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ON LIGHT AND OTHER HIGH FREQUENCY PHENOMENA.*

BY NIKOLA TESLA.

[*Concluded from p. 360.*]

It is certainly more nearly in accord with many phenomena observed with high frequency currents to hold that all space is pervaded by free atoms, than to assume that it is devoid of these, and dark and cold; for so it must be if filled with a continuous medium, since in such there can be neither heat nor light. Is then energy transmitted by independent carriers, or by the vibration of a continuous medium? This important question is as yet by no means positively answered. But most of the effects which are

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here considered, especially the light effects, incandescence, or phosphorescence, involve the presence of free atoms and would be impossible without these.

In regard to the incandescence of a refractory button (or filament) in an exhausted receiver, which has been one of the subjects of this investigation, the chief precautions, to be observed in constructing such bulbs, may be summed up as follows:

(1) The button should be as small as possible, spherical, of a smooth or polished surface and of that refractory material which best withstands evaporation.

(2) The support of the button should be very thin, and screened by an aluminum and mica sheet, such as I have described on another occasion.

(3) The exhaustion of the bulb should be as high as possible.

(4) The frequency of the currents should be as high as practicable.

(5) The currents should be of a harmonic rise and fall, without sudden interruptions.

(6) The heat should be confined to the button by enclosing the same in a small bulb or otherwise.

(7) The space between the walls of the small bulb and the outer bulb should be highly exhausted.

Most of the considerations which we have just considered as applying to the incandescence of a solid may likewise be applied to phosphorescence. Indeed, in an exhausted vessel the phosphorescence is, as a rule, primarily excited by the powerful beating of the electrode stream of atoms against the phosphorescent body. Even in many cases where there is no evidence of such a bombardment, I think that phosphorescence is excited by violent impacts of atoms, which are not necessarily thrown off from the electrode but are inductively acted upon from the same through the medium or through chains of other atoms. That mechanical shocks play an important part in exciting phosphorescence in a bulb may be seen from the following experiment. If a bulb, constructed like that illustrated in *Fig. 10*, be exhausted as thoroughly as possible, so that the discharge

cannot pass, the filament *f* acts by electrostatic induction upon the tube *t* and the latter is set in vibration. If the tube *o* be rather wide, about an inch or so, the filament may be so powerfully vibrated that when it strikes the glass tube it excites phosporescence. The phosphorescence, however, ceases when the filament comes to rest. The vibration can be arrested and again started by varying the frequency of the currents. Obviously, the filament has its own period of vibration, and if the frequency of the currents is such that there is resonance, it is easily set vibrating, though the potential of the currents be small. I have often observed that the filament in the bulb is destroyed by such mechanical resonance. The filament vibrates, as a rule, so rapidly that it cannot be seen, and the experimenter may at first be mystified. When such an experiment as the one described is carefully performed, the potential of the currents may be extremely small, and for this reason I infer that the phosphorescence is then due to the mechanical shock of the filament against the glass, just as it is produced by striking a loaf of sugar with a knife. The mechanical shock produced by the projected atoms is easily noted when a bulb containing a button is grasped in the hand and the current turned on suddenly. I believe that a bulb could be shattered by observing the conditions of resonance.

In the experiment before cited, it may of course be said that the glass tube, upon coming into contact with the filament, retains upon the point of contact a charge of a certain sign. If now the filament again touches the glass on the same point while it is oppositely charged, the charges equalize, with an evolution of light. But nothing of importance would be gained by such an explanation. It is unquestionable that the initial charges given to the atoms or to the glass play some part in exciting phosphorescence. So, for instance, if a phosphorescent bulb be first excited by a high frequency coil, by connecting it to one of the terminals of the latter, and the degree of luminosity noted, and then the bulb be highly charged from a Holtz machine by attaching it preferably to the positive terminal of the machine,

it is found that when the bulb is again connected to the terminal of the high frequency coil, the phosphorescence is far more intense. On a previous occasion I considered the possibility of some phosphorescent phenomena in bulbs being produced by the incandescence of an infinitesimal layer on the surface of the phosphorescent body. Certainly, the impacts of the atoms are powerful enough to produce intense incandescence by their collisions, since they quickly bring to a high temperature a body of considerable bulk. If any such effect exists, then the best known appliance for producing phosphorescence in a bulb, is a disruptive discharge coil giving an enormous potential with but few fundamental discharges, say 25 to 30 per second, just enough to produce a continuous impression upon the eye. It is a fact that such a coil excites phosphorescence under almost any conditions and at all degrees of exhaustion, and I have observed effects which appear to be due to phosphorescence even at ordinary pressures of the atmosphere, when the potentials are extremely high. But if phosphorescent light is produced by the equalization of charges of electrified atoms (whatever this may mean ultimately), then the higher the frequency of the impulses or alternate electrifications, the more economical will be the light production. It is a long known and noteworthy fact that all the phosphorescent bodies are poor conductors of electricity and heat, and that all bodies cease to emit phosphorescent light when they are brought to a certain temperature. Conductors, on the contrary, do not possess this quality. There are but few exceptions to the rule. Carbon is one of them. Becquerel noted that carbon phosphoresces at a certain elevated temperature preceding the dark red. This phenomenon may easily be observed in bulbs provided with a rather large carbon electrode (say a sphere of six millimetres diameter). If the current be turned on after a few seconds, a snow-white film covers the electrode, just before it becomes dark red. Similar effects are noted with other conducting bodies, but probably not many scientific men will attribute them to true phosphorescence. Whether true incandescence has anything to do with phosphorescence

excited by atomic impact or mechanical shocks, still remains to be determined, but it is a fact that those conditions which tend to localize and increase the heating effect at the point of impact are almost invariably the most favorable for the production of phosphorescence. So, if the electrode be very small, in other words, if in general, the electric density is great, if the potential be high, and if the gas be highly rarefied (conditions implying high speed of the projected atoms, or matter, and consequently violent impacts), the phosphorescence is very intense. If a bulb provided with a large and a small electrode be attached to the terminal of an induction coil, the small electrode excites phosphorescence, while the large one may not do so, because of the smaller electric density and hence smaller speed of the atoms. A bulb provided with a large electrode may be grasped with the hand while the electrode is connected to the terminal of the coil and it may not phosphoresce, but if, instead of grasping the bulb with the hand, the same be touched with a pointed wire, the phosphorescence at once spreads through the bulb, because of the great density at the point of contact. With low frequencies it seems that gases of great atomic weight excite more intense phosphorescence than those of smaller weight, as for instance, hydrogen. With high frequencies the observations are not sufficiently reliable to justify a conclusion. Oxygen, as is well known, produces exceptionally strong effects, which may in part be due to chemical action. A bulb with hydrogen residue seems to be most easily excited. Those electrodes which are most easily deteriorated produce the most intense phosphorescence in bulbs, but the condition is not permanent because of the impairing of the vacuum and the deposition of the electrode matter upon the phosphorescent surfaces. Some liquids, as oils for instance, produce magnificent effects of phosphorescence (or fluorescence?), but they last only a few seconds. So if a bulb have a trace of oil on the walls and the current is turned on, the phosphorescence only persists for a few moments until the oil is carried away. Of all bodies so far tried, sulphide of zinc seems to be the most susceptible to phosphorescence. Some samples obtained in Paris through the

kindness of Professor Henry were employed in many of these bulbs. One of the defects of this sulphide is, that it loses its quality of emitting light when brought to a very moderate temperature. It can, therefore, be used only for feeble intensities. An observation which might deserve notice is, that when violently bombarded from an aluminum electrode it assumes a black color, but singularly, it returns to the original condition when it cools down.

The most important fact arrived at in pursuing investigations in this direction is, that in all cases it is necessary, in order to excite phosphorescence with a minimum amount of energy, to bear in mind that no matter what may be the frequency of the currents, the degree of exhaustion and the character of the bodies in the bulb, there is always a certain potential (assuming the bulb excited from one terminal) or potential difference (assuming the bulb to be excited with both terminals) which produces the most economical result. If the potential be increased, considerable energy may be wasted without producing any more light, and if it be diminished, then again the light production is not as economical. The exact condition under which the best result is obtained seems to depend on many different circumstances, and the subject requires further investigation. In the meantime the required condition must be approximated as closely as possible in order to obtain the most favorable results.

Coming now to the most interesting of these phenomena, the incandescence or phosphorescence of gases, at low pressures or at the ordinary pressure of the atmosphere, we must seek the explanation of these phenomena in the same primary causes; that is, in shocks or impacts of the atoms. Just as molecules or atoms beating upon a solid body excite phosphorescence in the same or render it incandescent, so when colliding among themselves they produce similar phenomena. But this is a very insufficient explanation and concerns only the crude mechanism. Light, as is well-known, is produced by vibrations, of inconceivable rapidity. If we compute, from the energy contained in the form of known radiations in a definite space, the force which is

necessary to set up such rapid vibrations, we find that though the density of the ether is incomparably less than that of hydrogen or of any other known body, the force is something surpassing comprehension. What is this force, which, in mechanical measure, may amount to thousands of tons per square inch? In the light of modern views, we call it electrostatic force. It is impossible to conceive how a body of measurable dimensions could be charged to so high a potential that the force would be sufficient to produce these vibrations. Long before any such charge could be imparted to the body it would be shattered into atoms. The sun emits light and heat, and so does an ordinary flame or incandescent filament, but in neither of these can the force be accounted for if it be assumed that it is associated with the body as a whole. Only in one way may we account for it, namely, by identifying it with the atom. An atom is so small, that if it be charged by coming in contact with an electrified body and if the charge be assumed to follow the same law as in the case of bodies of measurable dimensions, it must retain a quantity of electricity capable of accounting for these forces and for these tremendous rates of vibration. But the atom behaves singularly in this respect; it always takes the same "charge."

It is very likely that resonant vibration plays a most important part in all manifestations of energy in nature. Throughout space all matter is vibrating, and all rates of vibration are represented, from the lowest musical note to the highest pitch of the chemical rays; hence, an atom, or a complex of atoms, no matter what its period, must find a vibration with which it is in resonance. When we consider the enormous rapidity of the light vibration, we realize the impossibility of producing such vibrations directly with any apparatus of measurable dimensions, and we are driven to the only possible economical means of electrically setting up waves of light, that is, by so affecting the molecules or atoms of a gas as to cause them to collide and vibrate. We must then ask ourselves, how can free molecules or atoms be thus affected?

That they can be affected by electrostatic force, is

apparent from many of these experiments. By varying the electrostatic force we can agitate the atoms and cause them to collide so as to evolve heat and light. It is not incontestably demonstrated that we can affect them otherwise. If a luminous discharge is produced in a closed exhausted tube, do the atoms arrange themselves in obedience to any other than electrostatic force acting in straight lines from atom to atom? Only recently I investigated the mutual action between two circuits with extreme rates of vibration. If a battery of a few jars (*cc, cc, Fig. 32*) be discharged through a primary *P* of low resistance (the connections being as illustrated in *Figs. 19a, 19b* and *19c*), and if the frequency of vibration be many million, there are great differences of potential between points on the primary not

FIG. 32.—Electrostatic action between primary and secondary, with extremely high frequencies.

more than a few inches apart. These differences may be 10,000 volts per inch, if not more, taking the maximum value of the E.M.F. The secondary *s* is therefore acted upon by electrostatic induction, which is in such extreme cases of much greater importance than the electro-dynamic. To such sudden impulses the primary as well as the secondary are poor conductors, and therefore great differences of potential may be produced by electrostatic induction between adjacent points on the secondary. Sparks then may leap between the wires and streamers become visible in the dark if the light of the discharge through the spark gap *d d* be carefully excluded. If now we substitute a closed vacuum tube for the metallic secondary *s*, the differences of potential produced in the tube by electrostatic induction from

the primary are fully sufficient to excite portions of it; but as the points of certain differences of potential on the primary are not fixed, but are, generally, constantly changing in position, a luminous band is produced in the tube, apparently not touching the glass, as it should if the points of maximum and minimum differences of potential were fixed on the primary. I do not exclude the possibility of such a tube being excited by electro-dynamic induction only, for very able physicists hold this view; but, in my opinion, there is as yet no positive proof given that atoms of a gas in a closed tube may arrange themselves in chains under the action of an electro-motive impulse produced by electro-dynamic induction in the tube. I have been unable so far to produce striæ in a tube however long, and at whatever degree of exhaustion; that is, striæ at right angles to the supposed direction of the discharge or the axis of the tube, but I have distinctly observed in a large bulb, in which a wide luminous band was produced by passing a discharge of a battery through a wire surrounding the bulb, a circle of feeble luminosity between two luminous bands, one of which was more intense than the other. Furthermore, with my present experience of the subject, I do not think that such a gas discharge in a closed tube can vibrate as a whole. I am convinced that no discharge through a gas can vibrate. The atoms of a gas behave very curiously in respect to sudden electric impulses. The gas does not seem to possess any appreciable inertia to such impulses, for it is a fact, that the higher the frequency of the impulses, the greater the freedom with which the discharge passes through the gas. If the gas possesses no inertia it cannot vibrate, for some inertia is necessary for free vibration. I conclude from this that if a lightning discharge occurs between two clouds, there can be no oscillation, such as would be expected in view of the capacity of the clouds. But if the lightning discharge strike the earth, there is always vibration in the earth, but not in the cloud. In a gas discharge each atom vibrates at its own rate, but there is no vibration of the conducting gaseous mass as a whole. This is an important consideration in the great problem of producing light eco-

nomically, for it teaches us that to reach this result we must use impulses of very high frequency and necessarily also of high potential. It is a fact that oxygen produces a more intense light than hydrogen, in a tube. This is because oxygen atoms possess more inertia and the vibration does not die out instantly. But then nitrogen should be as good, as oxygen, while chlorine, and the vapors of many bodies should be much better unless the magnetic properties of oxygen come prominently into play. Or, is the process in the tube of an electrolytic nature? Many observations certainly indicate that it is, the most important of these being that matter is always carried away from the electrodes, so that the vacuum in a bulb cannot be permanently maintained. If such a process takes place in reality, then again must we have recourse to high frequencies, for, with such, electrolytic action should be reduced to a minimum, if not rendered entirely impossible. It is an undeniable fact that with very high frequencies, provided the impulses be of a

FIG. 33.—Carbon deposit in tube in a magnetic field.

harmonic nature, like those obtained from an alternator, there is less deterioration and the vacua are more permanent. With disruptive discharge coils, there are sudden rises of potential and the vacua are more quickly impaired, for the electrodes are deteriorated in a very short time. It was observed in some large tubes, which were provided with heavy carbon blocks B B_1, connected to platinum wires w w_1 (as illustrated in *Fig. 33*), and which were employed in experiments with the disruptive discharge instead of the ordinary air gap, that the carbon particles under the action of the powerful magnetic field in which the tube was placed, were deposited in regular fine lines in the middle of the tube, as illustrated. These lines were attributed to the deflection or distortion of the discharge by the magnetic field, but why the deposit occurred principally where the field was most intense did not appear quite clear. A fact of interest like-

wise noted was that the presence of a strong magnetic field increases the deterioration of the electrodes, probably by reason of the rapid interruptions it produces, whereby there is actually a higher E.M.F. maintained between the electrodes.

Much might be said about the luminous effects produced in gases at low or ordinary pressures. With the present experiences before us, we cannot say that the intimate nature of these charming phenomena is sufficiently

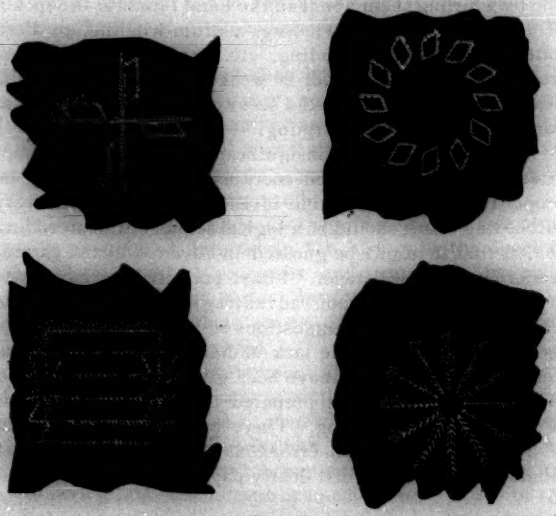

FIG. 34.—Spoke wheel, drum winding, alternate motor winding, ring winding. Some of the designs produced by intermittent discharges.

known. But investigations in this direction are being pushed with exceptional ardor. Every line of scientific pursuit has its fascinations, but electrical investigation appears to possess a peculiar attraction, for there is no experiment or observation of any kind in the dominion of this wonderful science which would not forcibly appeal to us. Yet to me it seems, that of all the many marvellous things we observe, a vacuum tube, when, excited by an

electric impulse from a distant source, it bursts forth, out of the darkness illuminating the room with its beautiful light, is as lovely a phenomenon as can greet our eyes. More interesting still it appears when, by reducing the fundamental discharges across the gap to a very small number and waving the tube about we produce all kinds of designs in luminous lines. So, by way of amusement, I take a long straight tube, or a square one, or a square attached to a straight tube, and by whirling them about in the hand I imitate the spokes of a wheel, a Gramme winding, a drum winding, an alternate current motor winding, etc. (*Fig 34.*) When seen from a distance the effect is weakened and much of its beauty is lost, but to one who sees the phenomenon close at hand it is irresistibly charming.

In presenting these insignificant results, I have not attempted to arrange and coördinate them as would be proper in a strictly scientific investigation in which every succeeding result should be a logical sequel of the preceding one, so that it might be guessed in advance by the careful reader or attentive listener. I have preferred to concentrate my energies chiefly upon advancing novel facts or ideas which might serve as suggestions to others, and this may serve as an excuse for the lack of harmony. The explanations of the phenomena have been given in good faith and in the spirit of a student prepared to find that they admit of a better interpretation. There can be no great harm in a student taking an erroneous view, but when great minds err, the world must dearly pay for their mistakes.

THE HISTORY AND MODERN DEVELOPMENT OF THE ART OF INTERCHANGEABLE CONSTRUCTION IN MECHANISM.

By W. F. Durfee.

I am to speak to you of the history and modern development of the art of interchangeable construction in mechanism.

This subject is so vast that it is impossible to treat it exhaustively in a single paper; nothing short of a copiously illustrated volume can convey an adequate understanding of the long, devious and weary way traversed by mankind in the journey towards the highest attainable perfection in handiwork, tools, machinery and their products.

The most that I hope to succeed in doing on this occasion, is to excite an interest in the history of the development of mechanical processes and apparatus, by brief notices of the more important inventions which, like milestones, mark the various stages of the road along which improvement has journeyed.

The study of the development of the mechanical adaptation of means to ends, is as essential to the thorough education of an engineer, as is a knowledge of biblical history, and of the lives of the fathers, to a theologian, or an acquaintance with Cæsar's commentaries and Jomini's Art of War to a soldier who aspires to command. Study of the laws of success is always assisted by an investigation of the causes of failure. Mechanical progress in the future can receive no more powerful acceleration than that furnished by a thorough knowledge of the laws underlying the successes and failures of past time.

That great Scotch-Englishman, Thomas Carlyle, tells us that: "Man is a tool-making animal; weak in himself, and of small stature, he stands on a basis, at most for the flattest-soled, of some half square foot, insecurely enough; has to straddle out his legs, lest the very wind supplant him.

Feeblest of bipeds! Three quintals are a crushing load for him; the steer of the meadow tosses him aloft like a waste rag. Nevertheless, he can make tools; can devise tools; with these the granite mountain melts into light dust before him; he kneads glowing iron as if it were soft paste; seas are his smooth highway, winds and fire his unvarying steeds; nowhere do we find him without tools; without tools he is nothing; with tools, he is all." Let us examine some of the work of this tool-devising and tool-using animal, and note his exercise of the creative power, with which he has been endowed, in the invention of tools and processes that enable the artisans of our day to produce those marvels of interchangeable mechanism which are the crowning glory of human skill in these closing years of the nineteenth century.

In looking backwards through the long perspective of the receding centuries for the first indication of an appreciation by man of the advantages of interchangeable construction, we recognize in the hands of the pioneers of the race, as they emerge from that "great deep" which, "without form and void," lies beyond the limits of authentic history, weapons and tools that possess the elements of interchangeability in as high a degree of development relatively to the knowledge of the times, as the most refined illustration of the art in our own day.

The bow of the primeval man had a sinewy string that would fit any other bow; his arrows were adapted to any bow-string; his paddle could be used in any canoe; the head of his spear would fit any shaft, and his uncouth hammer of stone, from the great interchangeable manufactory of nature, could drive a tent peg into the earth or a crush skull into fragments.

There is nothing improbable in the supposition that all the primitive arts originated in man's necessities and that a very general diffusion of a successful practice of those first essential processes was not only the explanation of their preservation but was the creator of wants more or less artificial. To satisfy these, other arts were devised, which in their turn led the way to more complex needs; one satisfied want

creating an unsatisfied desire, which inventive genius gratified.

Thus, step by step, through long ages past, mankind has progressed.

This slow engrafting of the artificial upon the natural man, has been noticed by many ancient writers. Virgil says:

> "Jove willed that man, by long experience taught,
> Should various arts invent by gradual thought."

Those who undertake to trace backward the development of civilization, cannot fail to note that all the more important inventions and discoveries have had, as a rule, more than one claimant. This rule has so frequently asserted itself, that it seems to justify the belief, that, when in the fulness of time, the world had become prepared for a decisive advance in the sciences or the arts, an overruling power indicated simultaneously to minds separated oftentimes by continents and oceans, some way to satisfy the growing needs of mankind.

Those whose prophetic minds are caused to see clearly, not only the scope of a pressing need, but also the means of satisfying it, we call discoverers and inventors; and such are deserving of honor and reward commensurate to the value of their services in the cause of human progress; but, unfortunately, they have too often been defrauded of a just recognition, and some paltry pilferer has been allowed to appropriate a recompense to which he had no righteous claim. A conspicuous instance of honor bestowed upon the undeserving, is furnished by the name of the Western World: Emerson tells us that Amerigo Vespucci, a "pickle dealer at Seville, who went out in 1499, a subaltern with Hojeda, and whose highest naval rank was boatswain's mate in an expedition that never sailed, managed in this lying world to supplant Columbus and baptize half the earth with his own dishonest name."

Names long established in geography and politics are not readily interchangeable, but, were it otherwise, one of the just results of this grand gathering of the nations on the soil of the continent discovered by Columbus, would be

the substitution of his name in all coming time for that of the "pickle dealer of Seville."

The term "interchangeable," as applied to mechanism, implies an ability to make a machine and all its component details exactly like a model; and if, in the making of a multitude of examples of a specific machine, the several details are made exactly like those of the model, it is obvious that any one of these details can take its appropriate place, and perform perfectly its allotted functions in any one of the machines.

In decorative art, what is sought is a systematic and pleasing adaptation of ornamental variety to the requirements of a particular object or situation, and uniformity of detail generally involves a sacrifice of artistic effect; but in the design of mechanism true art consists in the fitness of all the parts for their intended structural and functional purposes; and in the duplication of machines, conspicuous uniformity never advertises the poverty of art, but rather, by a satisfying sense of the "eternal fitness of things" mechanical, furnishes a material realization of true beauty, which has been defined as "the completeness of the whole, and the perfection of the parts."*

The more prevalent modern idea of the interchangeable in mechanism, supposes a super-refinement of accuracy of outline and general proportions that is not always necessary or even desirable. It would be a criminal waste of time and substance to fit a harrow tooth with mathematical accuracy, but yet any harrow tooth should have a practically interchangeable relation to all harrows for which it is designed. The instructive rewards of folly would certainly overtake him who should attempt to make "plow-shares" and "coulters" with radical exactness; nevertheless, these essential parts of plows should be interchangeable among all plows to which they are adapted.

It is fortunate that there is a recognized practical roughness of interchangeability, and that the refinements of agri-

* "True beauty consists in the completeness of the whole, and the perfection of the parts."—Rev. Theodore Parker.

culture have not in our day reached the point which that great captain of romance, Lemuel Gulliver, tells us had been attained in the wonderful kingdom of Laputa, which he claimed to have discovered. This allusion to the common modern practice of making the parts of agricultural implements and mechanism roughly interchangeable, naturally calls to mind the earliest method of making the metallic parts of implements and apparatus in like manner—the art of casting.

This art has come down to us from a period of which history is ignorant, and from a people whose foot-prints have been obliterated by the dust and *débris* of countless centuries.

We shall never know who made the first crude casting or the circumstances attending its production. In that rude period, doubtless:

> "Th' invention all admir'd, and each how he
> To be th' inventor miss'd; so easy it seem'd,
> Once found, which yet unfound most would have thought
> Impossible!"

Few, if any, of the arts have had more potent influence than that of casting, upon the progress of humanity on its long journey from primitive barbarism to what each succeeding age, even to our own day, has complacently described as "modern civilization."

Whoever the discoverer of this art was, whether the Vulcan of Mythology or the Tubal Cain of the Scriptures, he is deserving of most honorable recognition; and if present civilization was disposed to be as just to its creators as that of ancient Greece, it would imitate its altars "to the unknown gods" by the erection of a monument of no mean proportions to the unknown inventors, who, by their discoveries, laid broad and deep the foundations of the arts of our time.

It is not germane to our purpose to dilate upon what has been accomplished by the art of casting among ancient peoples; examples of castings in brass and bronze, designed both for ornament and utility, abound in the museums of the world, but perhaps it may not be without interest, in considering the antiquity of casting in iron, to call your

attention to a matter of evidence that has not hitherto received much consideration.

It is well known that the heads of the battering machines used in ancient warfare were sometimes made of iron and shaped like the head of a ram; from this fact, and from the nature of its movement when in action, these machines were called battering-rams. The heads of these machines were exposed to a terribly destructive impact when in use, and therefore it is justifiable to suppose that they would have been made of a material easily shaped and from which duplicate heads could readily be supplied. Forged iron does not fulfil these conditions, for it was difficult to obtain in large masses at that time, and it is absurd to suppose that the ancients would have expended the time and labor necessary to carve a lump of wrought iron in the elaborately realistic way indicated by all the representations of battering-rams shown on ancient monuments. As it is certain that these "rams heads" were often made of iron, it appears to be more than probable that some tough variety of cast iron was used, in which case a new head could promptly take the place of a broken one, and the business of the siege go on without serious interruption.

Another evidence of the appreciation of the value of interchangeability of similar parts in ancient weapons of the heavier sort, is found in the gearing for twisting the funicular springs of catapults. This gearing is described by Rollin* as being made of cast brass or iron, but the Chevalier Folard† states that it was made of cast iron.

The origin of the catapult is uncertain, but it is believed to have been used by Nebuchadnezzar at the siege of Jerusalem and Tyre (588–586 B. C.)

Thus early did military engineers perceive the advantages of interchangeability among the more important similar metallic parts of machines of war; and thus early does cast iron appear as a material from which some of these parts were constructed.

* *The History of the Arts and Sciences of the Ancients.* By Mr. Rollin, 3 vol., London, 1768.

† *Histoire de Polybe*, Amsterdam, 1729.

Neglecting minor ancient examples of the interchangeability of parts produced by the art of casting, we come to the making of movable types.

This art is without doubt the most important exemplification of the grand results that have sprung from the original discovery that metals could be given any desired form by melting them and pouring them into moulds.

The printer's art rests firmly and solidly upon the art of casting; for the experience and skill of man for the past 450 years has utterly failed to find a satisfactory substitute for the art of casting by which to produce with requisite economy and precision the interchangeable type whose invention marks distinctly the beginning of a new era in the life of men upon the earth. As soon as movable types were invented, it became evident that extreme accuracy was essential in their production; in each variety of character in a "font" all types of the same letter must be alike both in "face" and "body," and the "bodies" of all type must be so related to each other, and to the "quads" and "spaces," that a given length of line can be perfectly filled. In the history of mechanical development nothing possible of attainment by ingenuity and handiwork has ever been asked of the artisans of the world that they did not immediately supply; and so this demand for a precision of execution unheard of before was met by workmen whose skill was quite equal, if not superior, to that of any of our time.

Some recent careful examinations and measurements of repetitions of the same word in "black letter" volumes about four centuries old, prove the correctness of the statement just made, for the agreement is quite as close as that noted in modern publications. In estimating the skill of the original type founders, we must not fail to remember that they were destitute of all those tools which are considered essential by modern skilled workmen for the production of accurate work in metal.

"Lathes," as then made, were crude and sporadic.

The "planing machine" was 300 years in the future, and the "shaping machine" fifty years more remote.

The "micrometer" was 180 years ahead of them.

The "milling machine" was far below their horizon of time.

The "black lead pencil" had not been invented; and the English unit of lineal measurement was a "barleycorn."

For the execution of good work, such as that required on the moulds for type, the type founder of those days was obliged to depend upon hammers, chisels, files, gravers, scrapers, grinding, the bow-drill, and burnishers; these were the tools which skilful hands and keen eyes then used in the shaping of metals.

While the originators and early practicers of the art of printing, who were also type founders, were successful in casting types that would interchange among those of the same founder; the types made by different founders would not interchange with each other, and it is to the credit of American artisans that they have perfected a system of manufacture by which it is quite possible to "make up" a "form of type" as large as the side of an ordinary newspaper, and, notwithstanding that the types may have come from half-a-dozen foundries, not a type will leave its place when the form is held horizontally by its "chase."

In recent years the art of casting type has been combined with the art of "composing" or assembling them into words and sentences. By means of exquisite mechanism actuated by power and controlled by keys properly fingered by the compositor, certain "letter matrices" are arranged in exact order at the bottom of a mould. Whenever a sufficient number of such matrices are assembled to form a line of predetermined length, melted type metal is forced into the mould, and as soon as it solidifies, the solid line of type (hence the name, "linotype," of the apparatus) is thrown out of the machine. This machine is a splendid example of the modern system of interchangeable construction, and for accuracy of workmanship and the perfect adaptation of means to ends, as well as for its rapidity of operation, it deserves to take rank among the wonders of human ingenuity.

The art of "stereotyping" is only an amplification of the art of casting single type, and to such perfection has the art

attained in some of the larger newspaper offices, that it is not unusual to make a *papier-maché* mould from the flat form of type, curve this mould to a proper radius, cast the "stereotype" from the mould, secure it to the cylinder of the fast press, and have the newsboys crying the *n*th edition of the *Heraldic Tribune* and *Cosmopolitan Sun*, within twenty minutes after the arrival of the "form" in the stereotype room of the printing office.

For the invention of the art of printing, the world is indebted to Germany, and if that great nation,

> "Renowned for arts and arms,
> For manly talent and for female charms,"

had never made any other contribution to the commonwealth of knowledge, it would still be entitled to the grateful homage of mankind throughout the ages yet to be.

So noble an art as that of printing deserves the best that thought of brain and skill of hand can give. It has made the possibility and potentiality of knowledge the common heritage of all lands and peoples, and constituted itself the integrator and conservator of the science of the whole world.

Nations may rise or fall, dynasties may perish; but so long as man dominates the earth, the art of printing will be the educator of the succeeding generations, and will hand down from father to son, even unto the end of time, the ever accumulating wisdom of the rolling years.

For more than a century after the invention of printing, very little progress was made in mechanical invention. Feebly and with uncertain grasp the intellectual powers of man contended with the physical forces of nature; and all the world seemed to be awaiting the coming of some dominant genius like that of the great Sir Francis Bacon, through whom came such revelations of the force and scope of inductive reasoning, as changed the currents of civilized thought and conferred new powers and possibilities upon the mind of man.

From the time of Lord Bacon, human intelligence seemed to arouse itself from the torpor of past ages, and to assert,

by manifestation of a latent ingenuity and with an ever growing confidence, its creative power and supremacy over material things. This growing belief in the vast possibilities of the future, respecting discoveries in science and inventions in art, was quaintly expressed by Sir Hugh Platt, who, writing in 1595,* says: "That it is time, and high time, to let the world and all posterity to understand, that if our English artists (whereof sundrie in my knowledge are of such rare and singular conceipt, as they are, yea, and would also be found willing, if the stipend of honor and merit were now propounded, fully to discover a world of new inventions), they would bring forth so many, so rich, and so inestimable buds and blossoms of skill, as neither any civil policy that hath been hitherto shut up in printed books, nor any religious charity that hath been so often and so divinely sounded in at our deaf ears, could yet produce or show any comparable effects unto them." After briefly specifying a dozen inventions, for each of which large claims are made, Sir Hugh says: "I have always found it in mine own experience, an easier matter to devise many and very profitable inventions, than to dispose of one of them to the good of the author himself." In which conclusion, probably, most modern inventors will agree.

Among the first elements of mechanism to be made interchangeable by means of machine tools was the toothed gear wheel. An appreciation of the advantages of accuracy in the form of its teeth and of uniformity in their spacing was first decisively manifested by makers of clocks and watches.

A general idea of a wheel dividing and cutting machine was first suggested by Dr. Hooke, in the latter part of the seventeenth century, but the first tool of the kind acutally used is believed to have been made in France, and to have been similar to one described in Bion's work on mathematical instruments, published in 1702. The French were very much in advance of other nations in the invention of tools and appara-

* *A discoverie of certaine English wants, which are royally supplied in this treatise.* By H. Platt, of Lincoln's Inn, Esquire, printed at London by P. S. for William Ponsonby, 1595.

tus for the making of clocks and watches. In a work published in Paris in 1741,* there are detail engravings of three gear-cutting engines, two of which have perforated dial plates, and the third a worm-wheel and screw, for regulating the spacing of the teeth in the wheel being cut. The method of originating the divisions in the plates of these French machines is not described, but about the same period Henry Hindley (the inventor of the "hour-glass worm") a clock and watchmaker of York, England, constructed a machine for cutting gears which had a perforated dial plate. In a letter to John Smeaton (dated fourteenth of November, 1748), he explains the method of dividing the plate of this machine. This method involved the employment of a mechanical device, which, in the language of the workshops, we would now call a "jig,"† and Hindley is believed to have made the first

* *Traité de l'Horlogerie Mèchanique et Pratique.* Par Thiout, Paris, 1741.

† *Tomlinson's Cyclopædia of Useful Arts.* Article, "Graduation."

Hindley's method was nothing more than an original, highly ingenious method of stepping. It is described in the letter referred to. The reason why it was not published until 1786 was, that Hindley entrusted it as a secret to Smeaton. He says: "First choose the largest number you want, and then choose a long plate of thin brass; mine was about one inch in breadth and eight feet in length, which I bent like a hoop for a hogshead, and soldered the ends together, and turned it of equal thickness upon a block of smooth-grained wood, upon my great lathe, in the air (that is, upon the end of the mandrel) one side of the hoop must be rather wider (thicker?) than the other, that it may fit the better to the block, which will be a short piece of a cone of large diameter; when the hoop was turned I took it off, cut and opened it straight again. The next step was to have a piece of steel bent in the form of per margin, which had two small holes in it of equal bigness, one to receive a small pin, and the other a drill of equal size. I ground the holes after they were hardened, to make them sound and smooth. The chaps formed by this steel plate were as near together as just to let the long plate through. Being open at the end, the chaps so formed would spring a little, and would press the long plate close by setting in the vice. Then I put the long plate to a right angle to the length of the steel chaps, and bored one hole through the long plate into which I put the small pin; then bored through the other hole, and by moving the steel chaps a hole forward, and putting in the pin in the last hole, I proceeded till I had divided the whole length of the plate. The next thing was to make this into a circle again. After the plate was cut off at the end of the intended number, I then proceeded to join the ends, which I did thus: I bored two narrow short brass

record of the use of such a tool. In the year 1783, an English mechanician by the name of Rehé, made a gear-cutting machine having a dial plate nineteen inches in diameter. Some of the cutters used in this machine were made of solid steel, and others had steel teeth inserted in a hub. The teeth of the cutters were shaped to give the proper profile to the teeth of the wheel being cut, and their general form is very suggestive of certain popular cutters used at the present time. As showing the estimation in which good machinery was held in England at the close of the eighteenth century, the fact that this machine was sold after the death of Mr. Rehé, for the sum of £700 may be of interest. As a companion to his gear-cutting, Mr. Rehé made a special machine for grinding and shaping its cutters. The work was done by revolving discs and cylinders of copper, fed with

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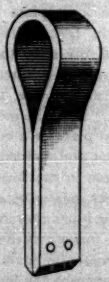
plates as I did the long one, and put one on the inside and the other on the outside of the hoop, whose ends were brought together, and put two or three screw-pins, with flat heads and nuts to them, into each end which held them together till I riveted two little plates, one on each side of the narrow plate on the outside of the hoop. Then I took out the screws, and turned my block down till the hoop would fit close on, and by that means my right



line was made into an equal divided circle of what number I pleased. The engine plate was fixed on the face of the block, with a steel hole fixed before it, to bore through, and I had a point that would fall into the holes of the divided hoop, so by cutting shorter and turning the block less, I got all the numbers on my plate. I need not tell you that you get as many prime numbers as you please, nor that the distance of the holes in the chaps must be proportioned to the length of the hoop."

emery and oil. This "cutter grinder" is believed to have been the first of a race whose various representatives in our day are regarded as indispensable aids to the production of accurate interchangeable work.

In the year 1775, Jesse Ramsden completed in London the most ingenious and perfect piece of mechanism that, up to that date, had been produced for accurate reduplication—his dividing engine—by which circles within its capacity could be divided into any desired number of equal parts. This machine immediately occasioned important changes in the construction of nautical instruments, and furnished the means for increasing the accuracy of the perforated dial plates of wheel-cutting machines; in fact, the plate of Rehé's machine, already mentioned, was divided upon Ramsden's engine. Although in the best modern dividing engines an automatic feature has been incorporated, they are, in the general principles of their construction, but copies of the invention of Ramsden, which conferred new powers upon science and a greater refinement of skill upon the fingers of art.

The facility with which the cutters used in the various early gear-cutting machines, removed the metal in front of them when in operation, naturally suggested the employment of similar cutters for finishing flat surfaces, and the irregular outlines of a large variety of shapes in metal; but the progress of the idea was exceedingly slow, and in its development for general purposes mechanicians failed to study carefully the behavior of the cutters of that parent of all milling machines—the gear-cutting engine. This lack of careful reasoning from one use to another resulted in the fact that milling cutters, until very recent years, have been run utterly wrong with a degree of precision most wonderful in its results, but which is not especially creditable to the powers of observation and analysis of those responsible for doing so right a thing in so wrong a way. A boy whittling a stick should have been a good object lesson in this connection. The first milling machine for shaping the surface of metal of which we have any account, is illustrated in the French encyclopædia, the publication of which was completed

in 1772. This machine was designed for finishing the exterior of musket barrels, and, if properly managed, it could not fail to make every barrel of precisely the same shape. Milling machines were designed and used by Eli Whitney in the manufacture of muskets in the early years of the century, and James Nasmyth introduced the use of milling cutters ("rotary files," they were then called) into England in 1829, for finishing hexagon nuts, and later extended their use to other work. In America, the milling machine, in its various forms and adaptations, as manufactured by the Brown & Sharpe Manufacturing Company, the Brainard Milling Machine Company, the Pratt & Whitney Manufacturing Company, and many other makers of repute, executes a large proportion of the interchangeable work made. In the manufacture of fire-arms about forty per cent. of the machine tools used are some form of milling machines. Of one well-known and approved type of milling machine, known as the "Lincoln Miller" (originally designed by Mr. F. A. Pratt), or of substantial copies thereof, it is believed that at least 150,000 have been sold within the past thirty years.

Although the milling machine is perhaps more generally used for small work, in America than in any other country, yet we have been very slow to recognize its great value for the larger work for which it has been successfully employed abroad. Forty-five years ago there was built in England a milling machine for cutting out of the solid metal, and finishing at one operation, the inside cranks of locomotives. This machine had a cutting disc fifty-one inches in diameter, armed with inserted cutters moving at a circumferential speed of twenty-eight feet per minute with a forward feed of three and one-half inches per hour. The width of the cut was four inches, its thickness eleven inches, and its length, exclusive of the crank pin, fifteen inches. After the throat of the crank was cut out, the forward feed was stopped, and the shaft then given a rotation about the centre of the crank pin. The whole operation of cutting out the throat and finishing the pin was completed in nine and one-half hours. Notwithstanding the hints furnished

(certainly as early as the year 1702) by the use of circular revolving cutters for the purposes named, the mechanicians of the eighteenth century were many weary years in discovering that the same general ideas, so successfully used in metal cutting, could be made available in machinery for the working of wood; and it was not until the year 1777, seventy-five years after the first edition of M. Bion's work was published in France, and fifty-four after it had been translated into English,* that the first patent for the construction of circular saws for wood-working was issued. This patent was granted to Samuel Miller, of Southampton, England, on the fifth day of August, 1777. Among all the workers in wood at that time, there appears to have been no one able to transform the revolving cutter—that had been so long used for cutting metal—into the circular saw for the working of wood, and it was reserved for this Miller, a "sailmaker;" who by no conceivable accident ever used a saw of any kind in his handicraft, to invent what may fairly be regarded as the foundation of all the various rotary devices used in the manufacture of interchangeable articles of wood. In the year 1794, Sir Samuel Bentham, in association with his brother, the famous political economist, Jeremy Bentham, established at Queens Square Place, Westminster, the first manufactory of machines for the working of wood. These premises being soon found too small, No. 19 York Street was also occupied. The extent of the buildings justifies the inference that a large business was carried on. We are told by Professor Willis, in an address before the Society of Arts in 1852, that "there were constructed machines for all general operations in wood-work; including planing, moulding, rabbeting, grooving, mortising and sawing, both in coarse and fine work, in curved, winding and transverse directions, shaping wood in complicated forms, and that further, as an example, all parts of a highly-finished window-sash were prepared, also all the parts of an ornamental carriage wheel were made, so that

* *The Construction and Principal Uses of Mathematical Instruments.* Translated from the French of M. Bion, chief instrument maker to the French king, etc. By Edmund Stone, London, 1723.

nothing required to be done by hand but to put the component parts together." In 1797, the British Admiralty consented to the introduction of Sir Samuel Bentham's wood-working machinery into the dock-yards at Portsmouth and Plymouth. Machinery was made under the direction of Jeremy Bentham at the factory before-named. That the machinery made by Jeremy Bentham was thoroughly effective, was amply proved by evidence before a government commission, which awarded him £23,000 for the right to use it in the prisons and dock-yards of the kingdom.

The machines for the shaping of wood that were invented by Sir Samuel Bentham and carried into practice before the beginning of the present century, were very numerous and important; among them we find an improved rotary planing and moulding machine, a segmental circular saw, conical cutters for dovetailing, an undulating carriage for producing wave mouldings, cutter-heads for working two or more sides at once, tubular boring tools, cylinder saws (these, however, had been known as surgical instruments in the time of Hypocrates, 340 years B.C.), reciprocating and rotary mortising machines, bevel and curvilinear saws, rotary cutters for forming screw threads in wooden screws, and a large variety of other machinery for wood-working. In the year 1799, Sir Samuel Bentham recommended the adoption of the plans of Mark Isambard Brunel for the manufacture of ship blocks by machinery. The Admiralty authorized the construction of the machines, which were completed in 1806, and so efficient was their operation that the first year's saving was computed at £24,000, two-thirds of which was awarded to Brunel for the right to use his ingenious invention.

It has long been a popular belief that most, if not all, of the ideas involved in the construction of machinery for the manufacture of interchangeable constructions of wood, originated in America, but in view of the remarkable achievements of the Benthams and of Brunel, that opinion cannot be successfully defended, and we must take off our hats in acknowledgment of their great originality, and content ourselves with asserting that we have done mighty

work in developing the ideas we have inherited, and that America is the largest employer of wood-working machinery among the nations.

The lathe may safely be accounted the oldest of machine tools. Save that of the husbandmen, and of the tailor, and the art of lying, there is no art older than that of turning, for we are told that Adam and Eve were turned out of Eden, and the first turning tool ever mentioned in history is the flaming sword of the sentinel Cherubim which "turned every way."

It is certain that the "potter's wheel," doubtless the parent of all lathes, has been known from the earliest times. Potsherds are mentioned in the book of Job, and no ruins are so ancient that fragments of the work of the potter are not found therein. The transition from a rotation about a vertical axis, to revolution about a horizontal axis, and from shaping a soft mass of clay, with the fingers for turning tools, to the shaping of wood with a tool of iron or steel, seems to us at this day to be very simple and easy; but, judging from the exceedingly slow progress of the development of the art of wood-turning after its discovery, it is pretty safe to assume that several hundred years elapsed after the invention of the "potter's wheel" before anything like the rudest form of the wood-working lathe became known.

Diodorus Siculus attributes its invention to a nephew of Dædalus, named Talus, about 1240 B.C., but Pliny states that it was first used by Theodore of Samos about 740 B.C., and mentions one Thericles, who rendered himself famous by his dexterity in using it. The ancients employed it for turning a large variety of forms of vases, some of which they enriched with carvings. Centuries afterwards mankind began to perceive that the idea buried in the rotating mud of the "potter's wheel" could be still further expanded and made useful for the shaping of metals, and at this point in its history the lathe begins to assume importance as a contributor to the art of interchangeable construction.

In 1578, Jacob Bessoni published,* at Lyons, a remarkable

* *Theatrum Instrumentorum, Jacobi Bessoni Delphinatis, Mathematici Ingeniosissime.* Lugduni, Apud Barth Vincentini. Cum priveligio Regis. MDLXXVIII.

folio, containing sixty full-page copper-plates, illustrative of a variety of instruments and machines, among which are three engravings of lathes.

One of these contains a suggestion of a guide bar with a serpentine groove, and various holes designed to direct and assist in controlling the peculiar hand tool employed. This clumsy machine tool gives us a hint—somewhat feeble, it is true, but, still a reminder—that there was a feeling among the mechanicians of that day, that some machinery for turning irregular forms was desired, and that they had begun to grope around in the outer darkness where everything was unformed chaos, in the hope of discovering some means to satisfy that desire. Another of the plates in Bessoni's work, furnishes the first published suggestion for a screw-cutting lathe provided with a guide-screw, and the beginning of a slide rest, in means to solidly hold the cutting tool, while the screw being cut was moved longitudinally as it revolved in contact with it. The guide-screw, and in fact the whole structure of this lathe, is a crystallization of the uncouth, both in idea and in execution; but, nevertheless, it affords conclusive proof that there was a slowly developing demand for more exact work than had hitherto been possible, and that inventors were eneavoring to satisfy that demand.

The lathes described by Bessoni were all "dead-centre" lathes, and the work did not have a continuous rotation, but was alternately revolved by a cord, in a manner similar to a bow drill. This feature seems to have been common to all lathes prior to Bessoni's time. It seems strange that the economy of time, and the other advantages of a continuous rotation, as exemplified in the "potter's wheel," were not regarded by the makers of the early lathes.

The royal license and protection granted to Bessoni by Charles IX of France, for the publication of his invention, was really a royal patent for all the machines described, and, therefore, Bessoni's book may properly be regarded as the "drawings and specifications" of this early patent; which, if not the first, is certainly more comprehensive in its scope than any other ever granted to an inventor of machinery.

The announcement of the license of the king is such a curiosity of brevity and emphasis, that it is quite justifiable to quote it entire:

THE LICENSE OF THE KING.

By full and special license of the King, given to Master Jacques Bessoni, author of this present work, for ten years in the near future, dating from the day when the work is finished by the printer; all persons of whatever rank or condition they may be, are prohibited to make, counterfeit, engrave, sell or to consent thereto, even to the drawings for manufacturing the inventions contained in the present work, without the permission of its author. Upon the penalties contained and specified by said license. Given at Orleans in the year one thousand five hundred and sixty-nine on the twenty-seventh day of June. By the King in Counsel,

[SIGNED] BRULLART.

It may aid the comprehension of the relations of this work of Bessoni, to the science of the time, to know that when the above license was granted, Copernicus had been dead but twenty-five years. Tycho Brahe was but twenty-three years old, Galileo was in his fifth year, Elizabeth had reigned but ten years in England, and the Pilgrims were not to effect a landing on the "stern and rock-bound coast" of New England, until fifty-one years thereafter.

[*To be continued.*]

THE CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, November 21, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 21, 1893.

WM. H. GREENE, President, in the chair.

The Treasurer called attention to a mistake that had been made in proposing for membership the name of Mr. J. Benjamin Glavin, after that gentleman had already been elected at a previous meeting.

Mr. Pemberton, as a committee of one to prepare a memorial of our late fellow-member, Mr. R. A. Fisher, read his report, which was accepted, with a vote of thanks from the Section. The report is herewith appended to these minutes.

A bill from the Actuary of the Institute for stationery and postage in sending out notices, etc., amounting to $10.99, was approved by the Finance Committee, and referred to the Treasurer for payment. A bill from the Secretary for postage, amounting to $2.60, covering a period of two years, was similarly recommended for payment.

The Actuary was requested to make a draft in favor of R. Friedländer & Son, for 173·25 marks, to cover subscriptions to current journals now due.

The nomination of officers for the year 1894 was then taken up. For President, Prof. E. F. Smith and Dr. Wm. H. Greene were nominated, but Dr. Greene declined the honor of a second term of office, thus leaving Professor Smith the only nominee.

Mr. H. Pemberton, Jr., and Dr. L. B. Hall were nominated for Vice-Presidents, and, on motion, it was voted that nominations for Vice-Presidents be closed.

The recent incumbents of the offices of Secretary, Treasurer and Conservator were re-nominated for their several offices, after which in each case it was voted that nominations be closed. Messrs. Hooker, Haines and Boyer were nominated for membership on the Committee of Admissions, the remaining members of this committee to be as usual the President, Secretary, Treasurer and Conservator.

Mr. L. F. Kebler presented a paper, entitled "Notes on the Examination of Beeswax." This paper, which showed much care on the part of the author, both in the experimental work involved and in the review of the literature of the subject, was well received, and was discussed by the President, Dr. Jayne and Mr. Haines. The paper was referred for publication in the *Journal*.

Dr. Terne read a communication from Mr. Williams, of Wilmington, in which the writer stated that he had tried the method proposed by Mr. Pemberton of determining phosphoric acid in fertilizer analysis, and found it entirely satisfactory. Dr. Terne also stated that the method had been used in his own laboratory with excellent results. Dr. Terne then read an exceedingly interesting paper on "The Availability of Nitrogen in Mixed Fertilizers." This was discussed by the President, Mr. Pemberton, Dr. Jayne and Mr. Haines, and was referred for publication.

The Section then adjourned. WM. C. DEY, *Secretary.*

THE METHODS OF TESTING FATS AND OILS.

BY DR. ERNEST MAILLIAU.
Director of the Government Testing Laboratory, at Marseilles, France.

[*Read at a special meeting, held June 8, 1893.*]

[*Concluded from p. 388.*]

Mailliau Process, Mode of Procedure.—In a porcelain dish of 250 cubic centimeters capacity, fifteen cubic centimeters of the oil to be investigated are heated to about 110°, then there is slowly poured on the oil a mixture of ten cubic centimeters of a solution of caustic soda of 36° B., and ten cubic centimeters of alcohol of 90° B. When the mass boils it becomes clear and homogeneous; 150 cubic centimeters of hot distilled water are added and boiling continued to expel the alcohol. The fatty acids are displaced with ten per cent. sulfuric acid solution added in slight excess, and the pasty acids immediately collected with a small platinum spoon. They are washed by shaking several times in a test tube with an equal volume of cold distilled water. The drops of water are drained off and they are then poured into a tube 2·5 centimeters in diameter and 9 centimeters long; fifteen cubic centimeters of alcohol ninety-five per cent. and two cubic centimeters of three per cent. nitrate of silver solution are added. The tube is protected from the light in the water-bath at 90° C. until about one-third of the alcohol is expelled, which is replaced by ten cubic centimeters distilled water. The heating is continued a few minutes and the coloration of the insoluble fatty acids is observed. *The presence of*

cotton-seed oil in any proportion whatever causes a mirror-like precipitate of metallic silver, which blackens the fatty acids of the mixture.

The members of the Agricultural Committee, composed of the greatest savants of France, MM. Pasteur, Eug. Tisserand, Boitel, Chatin, Heuge, Hardi, Rissler, Schloesing, Ronna, Lavaland, Muntz, Prillieux, Maret, Hon. Baron Thenard and Liebaut, after having tested the process on 128 samples from different provinces, have had the kindness to confer upon me the gold medal for this method of analysis, and I will take the liberty to present the conclusions of their Secretary, M. Muntz, director of the laboratories de l'Institut National Agronomique: "The preliminary saponification applied to the examination of fatty matters constitutes a new method on which we can confidently rely, not only in the analyses of edible products but also of those used for industrial purposes and also for soaps." (February, 1889.)

Before proceeding with this monograph, it is, of course, well understood that the same processes can be used for the detection of peanut, sesame and cotton-seed oils, in all other fatty mixtures.

Peanut Oil.—Peanut oil, apart from the arachidic acid which it contains, presents no special characters, as you can observe by examination of the chart upon which are indicated its physical and chemical properties.

Sesame Oil.—The purity of sesame oil may be demonstrated by shaking ten cubic centimeters of oil, first with five drops of sulfuric acid of 53° B., then with five drops of nitric acid of 28° B. The oil undergoes a progressive change of color through various shades from light green to red. The final red coloring matter obtained by this oxidation process turns yellow by the action of alkalies and returns to its original color with acids. This curious phenomenon does not take place with other oils but is obtained sometimes when working on sesame oils slightly adulterated; besides, the industrial oils from hot pressing, though pure, may give negative results. I have devised a rapid process, especially applicable for the recognition of castor oil in the industrial sesame oils.

Maillian Process.—For the rapid identification of castor oil and sesame, ten grams of the oil are shaken up with four drops of sulfuric acid of 66° B., a drop of nitric acid of 40° is added and shaken violently. Pure sesame oil blackens immediately, while that containing castor oil remains turbid yellow.

Cotton-seed Oil.—Concerning this oil, from a chemical standpoint, we have nothing particular to say. From the industrial point of view we may state that this product becomes more useful every day. Its cheapness allows everybody to use it, and this fatty material daily augments its important place in the markets of the world.

We will pass rapidly over the drying oils, poppy seed, linseed, walnut, cameline, over those of the cruciferæ, colza, rape and mustard, as well as the oils of the sweet almond, hazel nut and castor, the properties of which are shown upon the chart.

I will take the liberty, however, of mentioning a rapid process which I have devised for detecting the presence of castor oil in other oils. It is well known that the oils in general are soluble in petroleum ether, while castor oil, which distinguishes itself by its solubility in alcohol, is likewise remarkable for its insolubility in petroleum ether. Unfortunately this insolubility disappears at the ordinary temperature when a soluble oil is adulterated with a small proportion of castor oil.

It is only necessary to demonstrate its insolubility by shaking in a test tube one volume of the oil to be examined with two volumes of petroleum ether, and cooling the mixture to — 16° C. At the end of a few minutes the mass coagulates, and the oil separates if castor oil is present, while the liquid remains homogeneous if it is pure. This phenomenon is especially curious because it will be noted that the freezing point of castor oil unmixed with petroleum ether is much lower than that of most other oils.

SOLID VEGETABLE OILS.

Cocoanut and Palm Nut Oils.—The production of these oils, which is continually increasing on account of their

extensive use in the manufacture of soap during the last few years, has been made the object of several adulterations. Independently of the general chemical and physical character of these oils, as well as the sulfuric saponification which I have mentioned, we can employ with good results the determination of the saturation equivalent with normal caustic soda solution.

These oils, containing a greater amount of the lower fatty acids, require for their saturation a larger quantity of sodium oxide. To recognize these oils, it is only necessary to determine the number of cubic centimeters of normal solution required for the saturation of five grams of the pure fatty acid, viz: cocoanut oil, 24·1; palm nut oil, 22·5; while the average of the other liquid oils is seventeen to eighteen cubic centimeters only. This process presents some inconveniences, especially when trying to discover adulteration in small quantities, because it must be noted that the adulteration of these oils is practised only within certain limits, otherwise their appearance would lead to its detection. Besides, when an oil is made from old or spoiled seeds, the saturation is a little less.

Since the detection of adulterations in these oils depends on variations of a few tenths of a centimeter which might be caused by variations in quality of the oils themselves, or the method of operating, it is necessary to be very circumspect in the use of this truly scientific process.

With palm nut oil this error might be greater because it is customary to balance the low saturation of the seed oils by the addition of cocoanut oil. As, for example, five grams of fatty acids from a mixture containing forty-five per cent. of palm nut oil, forty-five per cent. cocoanut oil and ten per cent. peanut oil, require precisely 22·5 cubic centimeters normal solution for their saturation.

Iodin Number.—This determination is very useful because these oils, being very rich in saturated acids, absorb much smaller quantities of iodin than most other oils. For example, peanut gives ninety-seven, while cocoanut and palm nut show only nine to sixteen. Unfortunately, this difference of seven between the maximum and minimum,

throws us out of the way for small quantities of admixture, so much so that different authors fail to agree upon the average variation; some giving eight to nine only, while we are accustomed to find from thirteen to fifteen.

To recapitulate, this process, which if it gave constant results would be excellent, fails to give sufficiently accurate indications to detect adulteration of cocoanut oil when in small proportions. It is worse with palm nut oil and of no value to distinguish between the two.

Continuing our investigations in another direction we have fortunately found a process which gives constant results when used upon these oils after a preliminary neutralization.

We have discovered that cocoanut and palm nut oils are entirely soluble in absolute alcohol. At a temperature of 30° to 31° C., the former requires two volumes, and the latter four volumes, for complete solution.

It is a curious phenomenon that the smallest addition of vegetable or animal oils destroys this solubility in the same quantities of absolute alcohol. The solubility of the mixture is not proportional to its composition, but the mixture acts entirely like a distinct body.

Mode of Procedure.—First operation: Twenty cubic centimeters of the oil are shaken in a test tube with forty cubic centimeters of ninety-five per cent. alcohol. This indispensable preliminary treatment may give certain indications. Oil, soluble in ninety-five cent. alcohol, castor and rosin oil, etc., are thus discovered, while mowrah and karite oils give a milky turbidity to the alcoholic stratum.

Second operation: Five cubic centimeters of the neutralized cocoanut oil are measured with a pipette into a graduated test tube and ten cubic centimetres absolute alcohol added. The temperature is raised to 31°, the tube shaken violently for half a minute and then immersed in a water bath, kept at a temperature slightly above that of the tube.

Pure cocoanut oil dissolves completely and the solution remains clear. Any addition of another fatty matter causes precipitation; the material in solution being in a state of

molecular equilibrium, which is destroyed by the slightest modification.

Cocoanut oil containing palm nut oil precipitates when the proportion of the mixture amounts to twenty per cent.; below this the mass remains turbid.

The verification of palm nut oil is made in the same manner, only using twenty cubic centimeters absolute alcohol instead of ten, temperature remaining the same, 30° to 31°. Five cubic centimeters of palm nut oil containing twenty per cent. or more of cocoanut oil, dissolves in fifteen cubic centimeters of absolute alcohol. In the same proportions pure oil does not dissolve, and the mixture remains turbid.

A mixture of cocoanut, palm nut and peanut oils, in such proportions that the oil would appear pure by the indices of saturation, would easily be discovered by this process.

If we work at a lower temperature, the proportion of absolute alcohol must be increased. For example, at 25° to 26° it is necessary to double the quantity; for five cubic centimeters of cocoanut oil, use twenty cubic centimeters of alcohol, and for the palm nut forty cubic centimeters.

The same method may be used to determine the purity of cocoanut and palm nut cakes by first extracting the oil by means of a solvent and then operating on it in the manner described.

This process, which I have had the honor to describe, when carefully executed, enables us to determine in a few minutes adulterations of these oils which might cause bad results in soap making, which employs hundreds of millions of kilograms per annum, and in agriculture, which uses the cakes for cattle food. This process was presented to the Academy of Sciences, October 12, 1892, by M. L. Troost, and has been the subject of a favorable report to the Minister of Agriculture.

Let us pass rapidly over palm oil, of which the principal chemical properties are not remarkable except its partial solubility in absolute alcohol which is ten per cent. Also we will pass over the mowrah, which, as I have already mentioned, is identified by the milky white turbidity which it communicates to alcohol by shaking.

Illepi Oil.—This product, the titer of which is 52°·5, and cotton-seed margarine, or stearine as it is called here, whose chemical reactions are the same as the oil itself, will not long detain us.

While closing the description of the solid vegetable oils, I wish to mention karite oil, which comes from the French province, Soudan, which I have been especially directed to investigate by the Chamber of Commerce of Paris, and the Chamber of the syndicate for the manufacture of soap and candles.

It was very important for us to know how to utilize the great forest which covers the largest part of French Soudan. It is composed chiefly of the wild acacia and the karite or butter tree. The natives collect the nuts which fall from the trees, crush the kernels, treat the pasty mass with boiling water, and skim off the fat which comes to the surface. This fat, which is solid at the ordinary temperature, is used as an edible butter.

Without speaking about the great uses to civilization of this product, I must mention its remarkable chemical properties. The fatty acids, having a titer of 52°·5 C. combine with soda to produce an extremely hard soap. For candle making they would probably give better results, after preliminary treatment to remove the resinoid matters which they contain and which hinder the crystallization of the fatty acids.

The presence of these resins lowers the saturation to 14·9, and, like the mowrah, this oil causes turbidity by shaking with alcohol. (Communication of M. Mailliau to the Société d'Encouragement of Paris in 1892.)

SOLID ANIMAL FATS.

These are colored brown by a stream of chlorine gas.

Butter.—The analysis of this material, which has attracted so much attention during the last few years, is not so difficult as some imagine, but requires the skill of a practical and experienced analyst. The specific gravity of butter is notably lower than that of tallow and lard. It is the same with the iodin number and the freezing point of the

A GENERAL COMPARATIVE TABLE FOR T

		Fatty Substance.	1 Density at 15° C.	2 Action of Nitrous Vapors.	3 Sulfuric Saponification.		4 Indices.			5 Freezing Point Oils.
					Absolute.	Relative.	Bromin.	Iodin.	Acetyl.	
1	Liquid Vegetable Oils.	Olive,	0·915 to 0·917	{Solidification. Elaidin melts at 32°}	35°	94°	500 to 544	80 to 84	4·7	+ 1 to 4°
2		Peanut,	{Unshelled, 917·5 Shelled, 921}	Liquid Mass.	46°	127°	530	97	3·5	— 1°
3		Sesame,	923	"	54°	150°	695	104	3·4	— 5°
4		Cotton-seed (edible),	922	"	52°	144°	645	108	15·3	— 12°
5		Poppy (drying),	925	"	80	222°	835	133	13·1	— 18°
6		Colza,	924·5	"	48°	133°	640	99	6·3	— 6°·5
7		Rape seed,	915	"	56°	155°	632	103	5·9	— 4°
8		Linseed,	932·5	"	121°	336°	1,000	156	8·7	— 27°·5
9		Walnut,	926	"	99°	273°	737	144	7·3	— 30°
10		Cameline,	926	"	52°	141°	817	132	7·5	— 18°
11		Beechnut,	921	"	59°	163°	652	106	6·1	— 18°
12		Mustard seed,	918	"	39°	108°	763	96	6·9	— 5° to c
13		Sweet almond,	918·5	Soft Consistence.	47°	130°	644	98	5·7	— 10°
14		Hazelnut,	917	Rather Firm.	31°	86°	561	87·5	4·9	— 21°
15		Castor,	965	Formation of Ricin-Elaidin.	40°	111°	589	84	15·3	— 18°
16	Solid Vegetable Fats.	Coprah,	924·5	Solidification.	17° 5	48° 5	74	12	—	{Solid 22°· Fusion 26°
17		Cabbage palm,	922	"	19°	52°·7	99	16	—	23°·5 26°·
18		Palm,	925	"	17°	47°	325	52	—	25° to 35° 33° t
19		Mowrah,	915	"	26°	71°	404	65·3	—	23° 27°
20		Margarin from cotton-seed oil,	920	Soft Consistence.	47°·5	136°	588	84	—	14° 28°·3
21		Illipi,	917·5	Solidification.	13°·5	37°	152	24·7	—	28° 39°
22		Karite,	917·7	"	28°·5	79°	416	67·2	—	23° 25°·5
23	Solid Animal Fats.	Butter,	920 to 936	Solidification.	Mean, 23°	Mean, 63°	260 to 216	26 to 35	—	29° to 31° 21° t
24		Suet,	{Mutton, 917 Beef, 915}	"	16°	44°	247	40	—	{33° to 36° 42° t 33° to 35° 38° t
25		Lard,	920	"	33°	91°	365	59	—	32° 34°
26	Miscellaneous.	Fish oil,	923 to 930	Liquid Mass.	50° to 200°	138° to 277°	761 to 872	123 to 141	—	Congeals at
27		Rosin,	1·08	—	—	—	718	116	—	—
28		Rosin oil,	960 to 990	Fluid Mass.	—	—	297	48	—	—
29		Commercial olein (oleic acid),	900	Solidification. Elaidic Acid.	24°	—	443 to 518	68·5 to 83·5	41 to 63	—
30		Mineral oils,	850 to 930	Liquid.	{Petrol., 3° Schist, 22°}	80 61°	80 130	23 21	—	—

R THE ANALYSIS OF FATTY MATTER.

oints of	6 Fusing Points of Fatty Acids.	7 Solidification of Fatty Acids.	8 Saturation by Na_2O. Number of Cubic Centimeters of Normal Liquid Absorbed by Five grs. of Fatty Acid.	9 Solubility in Absolute Alcohol. Number of Grams of Neutral Oil Dissolved by 1,000 Grams Alcohol.	10 Deviation of the Plane of Polarization.		Characteristic Properties.
o 4°	27°	23°	17 86	43	0·6 Sacchar.	1.	*Action of Nitrous Vapors.*—Operate by Cailletet's process, pouring on twenty grams oil six grams H_2SO_4 and nine grams HNO_3. The characteristic colorations are first, with H_2SO_4 green, second, with $H_2SO_4 + HNO_3$ gray, green; third, after boiling straw-yellow, H after cooling a hard mass, color of white butter
	31°	28°	17·82	66	Variable.	2.	Arachidic acid, $C_{20}H_{40}O_2$ (fusing point 75°), is characteristic and allows the detection of peanut oil in all oils containing it.
	26°	22°	17·70	41	"	3.	*Maillieu's Process.*—The red color obtained by treating the rectified fatty acid of the oil with hydrochloric acid, and sugar is characteristic. The fatty acid is first collected and melted in an oven.
	36° to 37°·5	35°	18·17	62	"	4.	*Maillieu's Process.*—The black color obtained by the reduction of $AgNO_3$ in the presence of the saponified products of the rectified oil is characteristic.
	26°·5	16°	18·13	45	— 0·7°	5.	Poppy oil when used as an adulterant of olive oil, prevents the solidification of the mass by the action of nitrous vapors.
'5	17°	16°	16·49	20	Variable.	6.	A solution of potassium hydroxid heated with unpurified colza oil blackens with lead acetate, and reddens with potassium nitroferrocyanid.
°·5	15°·5	15°	16·68	15	+ 10°	7.	Density and fusing points of the fatty acids
	23°	21°	17·98	70	Inactive.	8.	Density, freezing point, sulfuric saponification and iodin index.
	Fluid.	Fluid.	18·26	44	"	9.	Sulfuric saponification, iodin index, freezing points and fluidity of the fatty acid.
	"	"	17·90	78	— 3	10.	Iodin index, freezing point and fluidity of the fatty acid.
	24°	17°	18·18	45	Almost Inactive.	11.	*Brulle's Reagent.*—Two cubic centimeters nitric acid, 0·1 grams dried albumen, ten cubic centimeters oil; when agitated the mixture takes a characteristic vermilion tint.
to 0°	16°	15°	17·97	28	+ 3	12.	Sulfuric saponification and iodin index.
	14°	5°	18·22	39	Almost Inactive.	13.	Nitrous vapors and solidification of fatty acid.
	25°	23°	17·63	33	"	14.	Sulfuric saponification and freezing points.
	12°	4°	16·77	Soluble.	Mean = 43	15.	Density, solubility in alcohol and crystallizable acetic acid, insolubility in petroleum ether, deviation of the plane of polarization.
22°·5 to 26°·5	26°·5	22°·7	24·1	Soluble at 31° C. in 2 vol. alcohol.	Undetermined.	16.	*Maillieu's Process.*—The neutralized oil is soluble at 31° in twice its volume of absolute alcohol, and becomes insoluble on the addition of seed oils. Saturation, iodin index.
26°·5	27°	24	22·5	Soluble at 31° C in 4 vol alcohol.		17.	*Maillieu's Process.*—Like the preceding, but requires four volumes of absolute alcohol.
30° to 39°	46° to 47°	42° to 46°	18·5	400		18.	Density, sulfuric saponification, partial solubility in absolute alcohol.
7°	46°	42°·5	15·5	160		19.	Density, saturation, when shaken with alcohol gives a characteristic milky tint.
30°·3	46°	42°·5	18·2	61		20.	Iodin index, solidification of the oil; Maillieu's Process (4).
9°	56°	52°·5	17·7	260		21.	Sulfuric saponification, iodin index, fusing point of the fatty acids.
5°·5	56°·5	52°·5	14·9	80		22.	Fusing point of the fatty acids, saturation, when agitated with alcohol gives a characteristic milky tint.
22° to 32°	37° to 39°	35° to 37°	21·15	65·4		23.	Volatile fatty acids, iodin index, solidification of the neutral matter, saturation, microscopic examination.
32° to 46°	40° to 50°	45° to 47°	18·5	3·18		24.	Sulfuric saponification, solidification of the fatty acids, insolubility in absolute alcohol.
38° to 43°	40° to 48°	43° to 45°	18·25			25.	Sulfuric saponification, iodin index.
4°	35°	34°	18·12	43			
s at 0°	—	—	17·72	Cod Liver, 240		26.	Iodin index, solubility in alcohol (milky emulsion), fusion point of cholesterin.
	—	—	15·13	Soluble.	Mean = — 15°	27.	Density, saturation, solubility in alcohol, deviation of the plane of polarization.
	—	—	—	Almost Insoluble Cold.	+ 30°	28.	Density, deviation of the plane of polarization, insolubility in crystallizable acetic acid.
	+ 4° to + 12°	0° to + 8°	17·7	Soluble.	—	29.	Density, nitrous vapors, solubility in alcohol.
	—	—	—	Insoluble Cold.	—	30.	Density, iodin index, insolubility in alcohol.

Are colored brown by a current of chlorine.

neutral fat. The saponification and the solubility in absolute alcohol on the contrary are notably higher.

We can further confirm our results by microscopical examinations; melted butters showing under the microscope a collection of small regular spheres. Adulterated butter shows, on the contrary, abnormal figures, as well as crystals, which appear brilliant in the dark field of the polarizer.

By determining the fixed and volatile fatty acids, and the point of solubility in alcoholic toluene, a skilled analyst familiar with these processes can easily determine admixtures above ten per cent. Below this point, I do not believe any adulteration would be profitable. Natural butter contains about eleven per cent. soluble and volatile fatty acids and eighty-seven per cent. fixed fatty acids. Besides, alcoholic toluene dissolves it almost entirely.

Tallow.—The properties of tallow are so well known that they require no description. The distinction between beef and mutton tallow is a matter of interest and presents great difficulties from the chemical standpoint, and we can observe differences only by taking the melting and solidifying points of the neutral fat and those of the fatty acids.

Lard.—Lard adulterated with cotton-seed oil is easily tested with nitrate of silver. If the lard has been altered by time or by other causes, it is necessary before using this reagent upon the fatty acids, to take the precaution of purifying the fat in the manner in which I have indicated at the beginning of this lecture. We will thus avoid the slight reduction which is produced by decomposition products.

Some authors strongly believe in the use of the iodin number, which will give good results in the case of large admixtures, as well as for quantitative analysis of such a mixture. But it is quite illusory for the detection of a small proportion of cotton-seed oil, for we must consider that the iodin number of pure lard varies within considerable limits, and it would be possible to correct for the high iodine number of cotton-seed oil by the addition of tallow, which will lower it appreciably. In such a mixture the action of nitrate of silver on the fatty acids enables us to discover adulteration even below five per cent.

Tallow is detected by observing, under the microscope, the crystallization of the fat from ethereal solution.

VARIOUS OILS.

The following oils, which frequently are used for the adulteration of agricultural fatty materials, are easily detected:

Fish Oil:—by its iodin number, its solubility in absolute alcohol, the presence of cholesterin, and finally the brown coloration by chlorin, and red by caustic soda and phosphoric acid.

Resins:—by their density, their saturation, their solubility in absolute alcohol, and the deviation of the plane of polarization. Besides, it is easy to isolate them because the majority of compounds which they form with metallic salts are soluble in ether while those of the fatty acids are insoluble.

Resin Oils:—by their property of not saponifying with caustic soda, by their insolubility in glacial acetic acid, and by the characteristic purple coloration which they give with fuming stannic chloride.

Olein Oil of Commerce:—by its solubility in alcohol and by its specific gravity.

Finally, the mineral oils:—by their iodin numbers, their indifference to the action of caustic soda, and their insolubility in absolute alcohol at 15° C.

Gentlemen, we have nearly finished all we have to say in our lecture. The processes which we have just enumerated are applicable indiscriminately to fatty matters, both edible and industrial, for the determination of their purity, with an approximation sufficient for the majority of cases.

The results obtained will be more conclusive if they are compared with those from products of the same origin and known purity. Banish the thought that in this short discourse we have wished to indicate in an absolute manner those processes which must be used and those which should be rejected. We have desired only to explain the methods which have given us the best results in the thousands of analyses which we have had occasion to make on fatty materials, including 50,000 for olive oil alone.

Although most of the processes which I have just indicated were devised and perfected in our laboratory, and have been adopted by several governments, I have not, however, the presumption to feel that we have definitely finished this question. I consider, on the contrary, that in the vast unexplored region of the fatty series, we have only taken a few steps; but I feel at the same time that we are now in the possession of sensitive and scientific methods which permit us to detect mixtures, the determination of which has appeared impossible up to the last few years.

The mission with which I have been charged by the French and Tunisian Governments in the interests of commerce and industry, shows you to what extent these countries are desirous of facilitating the exportation of pure and satisfactory products. France furnishes the best growth of virgin olive oil, from Aix en Provence and Nice. Tunis, also, furnishes, but at a less price, olive oils of excellent quality, which we can certify without analysis, because the Government imposes such heavy export and import duties upon seed and seed oils that it would be impossible to practise the smallest amount of sophistication.

Those who deal in olive oils often make the remark that pure oil is too strong and that it is improved in flavor by a mixture with seed oil. Without discussing this inexact statement, I believe that it would be preferable in every instance for the dealer to buy pure olive oil and to make his own mixtures. He would thus profit by the difference in price, which averages about sixty francs per 100 kilograms.

I hope you will pardon the dryness of the subject which we have just discussed, in considering how important it is for our two countries to have the same means of making analyses of American and French products. When we arrive at a complete understanding, discussions and reclamations will become impossible, and I cannot better conclude than by expressing the sincere wish that its realization will permit the two republics to bind more closely together their commercial relations.

Thanks, gentlemen, for your kind attention.

THE ATOMIC WEIGHT OF MOLYBDENUM.

BY EDGAR F. SMITH AND PHILIP MAAS.

[*Read before the Chemical Section of the Franklin Institute, September 19, 1893.*]

The present atomic value assigned this element is based upon the results obtained by Dumas (*Ann. Chem. Pharm.*, **105**, 84, and **113**, 23), Debray (*Compt. rend.*, **66**, 734) and Lothar Meyer (*Ann. Chem. Pharm.*, **169**, 365). The method pursued by Dumas consisted in the reduction of molybdenum trioxide. Debray also adopted this procedure, but in addition made several experiments upon the precipitation of the trioxide in an ammoniacal solution by silver nitrate. Lothar Meyer's value (95·9) is deduced from results obtained by Liechti and Kemp (*Annalen*, **169**, 344) in their analyses of the chlorides, $MoCl_2$, $MoCl_3$, $MoCl_4$ and $MoCl_5$. The chlorine in each was determined as silver chloride and the molybdenum as disulphide. Clarke (*A Recalculation of the Atomic Weights*, Washington, 1882) expresses the opinion that the most reliable results are those that have been obtained by the reduction of the trioxide. Of the work of Liechti and Kemp, he remarks: "Traces of oxychlorides may possibly have contaminated the chlorides and augmented their atomic weight." Rammelsberg (*Berichte d. d. Chem., Gesellschaft*, **10**, 1776) made one experiment in the reduction of the trioxide, from which he calculated the atomic weight of molybdenum to be *96·18*.

Thinking that additional light could be thrown upon the magnitude of this constant by proceeding in a different direction, we utilized a reaction first observed by Debray (*Compt. rendus*, **46**, 1098; *Ann. Chem. Pharm.*, **108**, 250), which, in the hands of others (Péchard, *Compt. rend.*, **114**, 173; *Zeit. f. anorg. Chem.*, **1**, 262; Smith and Oberholtzer, *Journ. Am. Chem. Soc.*, **15**, 18, and *Zeit. f. anorg. Chem.*, **4**, 237) has proved to be a most excellent means of determining molybdenum and separating it from its intimate associate—tungsten. We refer to the action of hydrochloric acid gas upon molybdic

acid and molybdates, whereby the molybdic acid is volatilized with ease in the form of an hydroxychloride—$MoO_3.2HCl$. Numerous trials have demonstrated that the reaction expressed by the equation—

$$Na_2MoO_4 + 4HCl = 2NaCl + MoO_3.2HCl + H_2O$$

is quantitative. We exposed pure anhydrous sodium molybdate (at 150–200°) to the action of hydrochloric acid gas, volatilized the molybdenum, trioxide and from the weight of the residual sodium chloride calculated the atomic weight of molybdenum.

The sodium molybdate employed by us was Merck's purest preparation. We recrystallized it many times and then by a careful examination satisfied ourselves that it did not contain silica, sulphates, tungstates or alkaline carbonates—substances that might have been present. The purified salt was dried with extreme care until no further loss in weight was observed. In this anhydrous condition it was preserved in clean weighing bottles, which were kept in desiccators to exclude dust and moisture. The specific gravity of the anhydrous salt was determined, alcohol being used for the purpose. The value found was 6·9780. The balance employed by us was of the Sartorius design.*

The weights of brass and platinum were of Westphal make and had previously been carefully adjusted for this purpose.

Tared porcelain boats were used to carry the anhydrous sodium molybdate, which was exposed in hard glass tubes to the action of pure and dry hydrochloric acid gas. This was prepared from salt and pure sulphuric acid. The gas as it was evolved was first conducted through a U-tube half-filled with damp silver chloride; it next passed through two flasks containing sulphuric acid, then through a tower of dry calcium chloride and finally through clean cotton, after which it was admitted to the combustion tube where it came in contact with the sodium molybdate. A very gentle heat was applied to the latter and gradually

* We would here acknowledge our indebtedness to Dr. John Marshall, of the Medical Department, for the privilege of using this excellent instrument.

increased to from 150–200° C., beyond which the temperature was not permitted to rise. Moisture was excluded as much as possible. The volatilized $MoO_2.2HCl$ was collected in water. The boats containing the residual sodium chloride were allowed to cool in a slow current of hydrochloric acid gas, then transferred to vacuum desiccators, and the vapor repeatedly exhausted. The weights were taken after the boats had stood one hour. Second weighings were made after the boats had remained overnight in the dry desiccators and showed no appreciable alteration. Barometric pressure and temperature were carefully observed and all weighings reduced to the vacuum standard. Our results are as follows:

Na_2MoO_4 in Grams.	*NaCl in Grams.*	*Atomic Weight of Mo.*
1·14726	0·65087	96·130
0·89920	0·51023	96·094
0·70534	0·40020	96·108
0·70793	0·40182	96·031
1·26347	0·71695	96·087
1·15217	0.65367	96·126
0·90199	0·51188	96·067
0·81692	0·46358	96·077
0·65098	0·36942	96·073
0·80563	0·45717	96·078
Mean,		= 96·087
Maximum,		= 96·130
Minimum,		= 96·031
Difference,		= ·099

In our calculations we used the following values: Na = 23·05, Cl = 35·45 and O = 16. These have been taken from a revised table of atomic weights, published by Clarke, October, 1891.

The sodium chloride in five of the determinations just given was converted into silver chloride. From the calculated silver contained in the chloride we deduced the atomic value of molybdenum to be 96·10—the mean of five determinations. This figure we regard as confirmatory of the rest of our work.

The sodium chloride which we obtained dissolved readily

and to a clear solution in water. Molybdic acid was not found present in it. This was one of the points that we watched very closely, although its presence would have tended to diminish rather than to augment the atomic value found. Another cause of a like result would have been moisture absorbed by the sodium chloride. Against this source of error we likewise took every precaution, and consequently feel that the result *96·08* obtained by us approaches very closely to the true atomic magnitude of molybdenum.

UNIVERSITY OF PENNSYLVANIA, September 16, 1893.

THE ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, September 27, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 27, 1893.

ELMER G. WILLYOUNG, President, in the chair.

The stated meeting of the Electrical Section was called to order at 8·10 P. M., by President Willyoung, with twenty-one members and visitors present.

The minutes of the meeting of June 27th were read and approved.

The Treasurer reported a balance of $35.89 on hand, and presented bills for printing, $3, and postage and mailing of notices, $8.75, which were ordered paid.

A paper on "The Chloride Electrical Storage Battery," by Mr. Herbert Lloyd, was read by the author and discussed by Messrs. Hering, Spencer and Willyoung.

The meeting then adjourned. R. H. LAIRD, *Secretary.*

[*Proceedings of the stated meeting, held Tuesday, October 24, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 24, 1893.

ELMER G. WILLYOUNG, President, in the chair.

The stated meeting of the Section was called to order at 8 P. M., by President Willyoung, twenty-three members present.

In the absence of the Secretary, on motion, Mr. D. A. Partridge was appointed Secretary *pro tem.*

The reading of the minutes of the previous meeting was dispensed with.

The names of Mr. Bacon, E. R. Keller and G. C. Common having been proposed for membership, they were duly referred to the Committee on Admissions.

The Chair announced that a series of lectures, to alternate with the business meetings of the Section, had been arranged for, and that Dr. Henry Morton, Mr. J. J. Carty, Prof. Elihu Thompson and one or two others had expressed their willingness to address the Section.

Mr. Carl Hering read a most interesting collection of notes on "Recent Progress in Electricity Abroad," taken mostly from European journals.

Some interesting discussion was elicited upon many of the points touched upon in Mr. Hering's paper.

Mr. L. F. Rondinella exhibited a collection of lantern slides of subjects from the Columbian Exposition, and gave a short talk descriptive of the views.

On motion, adjourned. D. ANSON PARTRIDGE, *Secretary pro tem.*

NOTES ON RECENT DEVELOPMENTS IN ELECTRICITY ABROAD.—PART I.

BY CARL HERING.

[*A paper read at the stated meeting of the Electrical Section of the Franklin Institute, October 24, 1893.*]

Busy men, as most conscientious electricians are, generally have little time to study the vast amount of periodical literature published weekly, even if the journals were all accessible to them, and if the foreign languages in some of them were no hindrance. For the benefit of such busy men the following notes were compiled from articles in the principal foreign electrical journals for the present year; as they are all taken from periodicals, they necessarily contain nothing which has not already been published, and they are therefore intended to form a mere *résumé* or index to call attention to what has been done, leaving those who are interested in any of the subjects to look up further details for themselves.*

Electro-physics.—Taking up first the subject of electro-

* More complete abstracts of all the articles referred to will be found in the "Digest" of the *Electrical World*, from February 4, 1893, to date.

physics, I will limit myself to only a few of the more interesting papers, as most of that which has been published in this branch belongs to the subject of physics rather than to electrical engineering.

Mr. Arno has shown that a rotating electric field, quite similar to the well-known rotating magnetic field, can be produced, and that this can be applied to the construction of an electrostatic rotary field motor; it is only of theoretical interest, as the power developed is necessarily exceedingly small. There has been some discussion as to whether there is such a thing as electrostatic hysteresis, on which this phenomenon is supposed to be based, but authorities still differ.

Prof. Elihu Thomson states that he has succeeded in making a transformer in which a continuous current is made to give alternating currents of any desired frequency, and which contains no moving parts. Several other writers have shown how the frequency of an alternating current may be tripled and doubled quite readily in an alternator without increasing the speed. Dr. Sahulka has shown that a condenser may act as a transformer of current into phase, so to speak, that is, that a condenser in parallel converts a weak current of small phase difference into a strong current of large phase difference, and *vice versa*.

Several instruments have been described by means of which the curve of an alternating current can be resolved into its component sine curves.

Dr. Heydweiller has made a long series of tests with striking distances, giving quite a complete table of the results, which might be used to advantage in place of the very old table of De La Rive, which has been the standard of reference for so many years. The much-vexed question of the sparking distances has also been discussed by Mr. Peace, in a Royal Society paper, in which he gives what constitutes, probably, one of the most complete and reliable tests made for certain ranges. Mr. Precht has shown that lightning-rod points begin to discharge only when the potential has reached as high as 15,000 volts, and even extremely fine points can be charged to 2,500 volts before they will

discharge continuously; also that a bunch of points must be charged to a higher potential than a single point in order to discharge; he believes that in many cases the points of lightning rods are inactive. The difference of potential of the air at the top and at the bottom of the Eiffel Tower was found to vary from 3,000 to 7,000 volts, increasing sometimes to 10,000.

Mr. Arons described an arc lamp in which the arc is produced in vacuum between electrodes of mercury, showing some interesting results; the voltage and the current are quite low, but unfortunately the amount of light generated is not given.

In an interesting experiment made by Dr. Gore, he has shown that mechanical pressure may be converted into an electric current; the pressure is applied to an electrolyte, which then generates a current at the expense of nothing but the pressure.

A number of improvements have been described by Wimshurst and others in so-called electrostatic machines.

Numerous experiments have been described with stretched wires through which a current is passed; under certain conditions the wire will vibrate, some parts becoming luminous, while others remain cold; in another case the wire itself became deformed as if it had been placed between two files.

A number of articles have been published on the electrical transmission of sight, but although interesting, they appear to contain nothing new or of any great importance, and the matter may still be considered as an unsolved problem.

Much has been done in the line of the researches started by Hertz, but this is beyond the province of the present paper.

Professor Dewar has made some very interesting experiments with liquid oxygen, which he now makes in large quantities. Liquid oxygen is magnetic, and he has shown that in liquefied air the magnet will not suck out the oxygen, even though the nitrogen is not magnetic. But the most interesting parts of his researches, for electricians, are those which show that the resistance of all pure metals is probably zero

at the absolute zero of temperature; or, in other words, at that temperature electricity will pass through pure metals without any C^2R loss; alloys, however, do not follow this rule. Professor Dewar has also succeeded in converting air into a solid. It has been stated that the magnetic moment of oxygen is about one-thousandth that of iron, and that liquid oxygen is an excellent insulator.

Much has been written on the electro-magnetic theory of light, but it is beyond the province of this *résumé*. An English scientist stated that electro-magnetic waves are strictly similar in their nature to light waves, differing only in the wave length. The light waves are about one-fifty-thousandth of an inch long, while the electro-magnetic waves that have been investigated are from a few inches to many yards in length.

Messrs. Lagrange and Hoho gave what appears to be the first published description of the phenomenon, now so well known, of heating a metal by its contact resistance with water. The heat produced is exceedingly intense, and is generated very rapidly—two qualities which may make the process one of considerable commercial value.

It is claimed by Mr. Sanford that Ohm's law should be qualified, as he believes that he has found that the nature of the medium surrounding a wire has an appreciable effect on the resistance of the wire; his conclusions, however, do not appear to be generally accepted, and it will be fortunate if it turns out that he is not correct.

Mr. Packey claims to have found by photography that there is what he calls an electrical spectrum different from the remaining part of the spectrum, and that it contained only the "electric rays" of the spectrum.

Several papers have been written, showing how the amount of light can be measured by absolute instead of comparative methods, but none of these appear to have as yet been put into the form of a practical photometer.

A number of interesting phenomena have been described with high tension and high frequency currents, which, however, time does not admit of mentioning here. Much has been written lately endeavoring to explain the phenomenon

that an incandescent lamp may be brought to great brilliancy by high tension, high frequency currents of exceedingly small ampèrage; most of the writers claim that it is due to skin-deep conduction, but this has been seriously questioned by several equally high authorities, and it can therefore still be considered as a phenomenon which cannot be explained. Dr. Leduc has shown that high tension alternating currents produced by electrostatic machines have properties which are analogous, but not identical with, those which Tesla uses. Mr. Rimington has shown that many of the phenomena with vacuum tubes can also be produced with such tubes when they contain no electrodes, and when they are placed in electrostatic fields. Lord Armstrong showed an interesting experiment, in which a cotton thread was carried bodily from one glass of water into another by a current from an influence machine.

A new and important re-determination of the mechanical equivalent of heat has been made by Messrs. Griffiths and Clark; they found it to be 778·99 foot-pounds.

Among the interesting articles of a speculative nature is one in which a French writer endeavors to show that the absolute temperature has the same dimensions as electrical potential.

Magnetism.—Mr. Meylan has shown that the great care taken by some makers to have perfect joints in dynamos is not justifiable, as the additional excitation required to overcome the effects of joints in a magnetic circuit is only about one to two per cent.; in transformers, however, the question is quite different, for if joints could be avoided, there would be a gain of ten to fifteen per cent. in the magnetizing current; he believes furthermore that the pre-determination of the characteristics of transformers having a closed magnetic circuit is very uncertain, and probably of little practical value.

Mr. Abdank Abakanowicz has described an interesting arrangement by means of which the effects of hysteresis may be compensated in measuring instruments by the simple addition of a second electro-magnet, properly designed and proportioned.

In Russia, a local north pole of the earth's magnetism has recently been found, thus showing that there are at least two north poles of the earth.

Units, Measurements and Instruments.—Many new instruments and new methods for making various measurements were described, but they are too numerous to mention here. Those interested in the measurement of self-induction will find several articles on the subject in recent numbers of *La Lumière Électrique.* Professor Fleming, in his recent Cantor lectures, has given a very good summary of the subject of the practical measurement of alternating currents.

The very extended researches which have recently been made with the Clark standard cell seem to show that it may now be considered as a very reliable and accurate standard, provided it is properly made. On the other hand, it appears that the Daniell standard has been abandoned, at least when accuracy and reliability are of great importance. It appears that the Clark cell may now be relied upon within one part in 10,000; that is, within one-hundredth of one per cent.

A number of tests have been made of the Elihu Thomson wattmeter, all of those published giving very favorable results; this, coming from abroad, is significant. Professor Fleming has called attention to the fact that meters placed in cellars are often subjected to great changes of temperature, producing an error of from ten to fifteen per cent. in the readings, a subject which he thinks ought to be considered more than it is in designing meters. Several forms of ohmmeters have been described, chiefly for use in measuring high resistance and insulation. The literature on the copper voltameter has received an important addition by the paper of Dr. Ottel; he shows, among other things, that the addition of alcohol makes the actual deposit more nearly equal to that required by theory; also, that an acid solution is better than a neutral one.

Much has been written about locating faults in underground mains, but most of the methods are either impracticable or rather cumbersome, requiring the patience of a German to apply them. Apparently successful high resistances have been made, consisting of rods of a mixture of

plumbago and clay. An interesting and simple method for measuring the magnetic qualities of iron was described by Dr. Behn-Eschenburg, in which the underlying principle is that the magnetic circuit is suddenly broken, which enables both the permeability and the residual magnetism to be readily determined with very simple apparatus.

Much has been written, especially by the French and Germans, regarding the behavior and the calculation of condensers for commercial use in alternating current circuits; although interesting, the results will be of little use until condensers become cheap enough to be used in practice. A feature of interest, if true, for all condensers, was reported in an English paper; it was shown that a condenser which was excellent at normal temperatures, possessed very bad insulation when the temperature approached the freezing point of water.

Recent experiments with the arc have apparently shown that its temperature is constant, being about 3,500° C., and that the amount of light emitted per unit area of crater surface is also constant, for which reason some have urged its adoption as the unit of light; the amount of light given off per square millimetre of crater surface is given as about seventy candles. A French scientist suggests a photometric standard made of phosphorescent zinc sulphide, which, in common language, might be called luminous paint. If exposed to the light it will afterward emit light, the intensity of which seems to be independent of the original source of illumination, of its duration, and of the thickness of the layer. Among the different forms of photometers the Lummer-Brodhun type seems to be meeting with increasing favor. Several curious forms of photometers have been described, in one of which light is absorbed and measured by a semi-translucent screen of increasing thickness, and, in another, letters printed on successive sheets, each one with a darker background than the preceding, are used, but both are, of course, only very crude instruments.

For measuring extremely high temperatures, as in furnaces, and also for extremely low temperatures approaching the absolute zero, physicists seem to have found electrical

methods the most reliable. For high temperature thermometers, Dr. Barus concludes from a long series of experiments that a couple made of platinum with an alloy of platinum and iridium or rhodium gives the best results.

Mr. Lagarde has made a re-determination of the specific resistance of pure copper, and finds it to be 19·58 ohms, presumably legal ohms, at 0° C. for a wire 1,000 metres long and one millimetre in diameter. He also found that the temperature coëfficient ·00445 is fairly constant between 0° and 40° C., and that it is directly proportional to the conductivity of the copper.

A writer in a German paper calls attention to the fact that the shape of the waves of an alternating current will have quite a perceptible effect in the reading of a voltameter and in the working of an alternate current arc light, and he concludes therefrom that both should be adjusted with currents from the same generator with which they are to be used.

A French writer has devised an analytical method for determining the shape of the curves of alternating currents, consisting of an experimental determination of the successive terms in the Fourier series, from which the curve can then be deduced. The measurements are made with auxiliary apparatus used in connection with the alternator.

There was much discussion in foreign journals regarding the work to be done by the Chicago Congress, but as all this was entirely ignored by the delegates to that Congress it may be passed over here. Although it has been of little use, it was none the less interesting and instructive.

CHARLES A. COULOMB.

By Prof. Edwin J. Houston.

[*Read before the Electrical Section of the Franklin Institute at its stated meeting, March 28, 1893.*]

The eminent services of Charles A. Coulomb to physical science generally, and to the field of electricity and magnetism in particular, have long been recognized by the scientific world. When the custom arose of naming the practical electric units after distinguished electricians or physicists who had passed from their labors, Coulomb was remembered and the practical unit of electric quantity was named after him.

Portraits of all the scientists after whom the units of electricity are named, have been published, with, I think, the exception of Coulomb.

One of my former students, a grandson of Coulomb, has loaned me a eulogy on his grandfather by Delambre. This eulogy gives an excellent account of the civil and scientific services rendered by Coulomb to the world, and I have thought that a translation of the same, together with a photograph, taken from an oil painting now in the possession of the Coulomb family, might be of interest to the electric public.

I have, therefore, made a free translation of the article. The manuscript is in that illegible handwriting so often characteristic of genius. Indeed, this is true in the present case to such an extent that in all probability I may have erred in some respects in my translation. I believe, however, that this will be true to but a limited extent, especially as Prof. Bernard Maurice, Professor of French in the Central High School of Philadelphia, has kindly given my translation the benefit of his criticisms.

Although the translation can best speak for itself, yet a brief summary of the more important of M. Coulomb's contributions to physical science may be of interest.

The field which M. Coulomb occupied in science was a

varied one. His earlier work comprised the construction of submarine works with means for laying foundations without previous drainage.

He also early in life conducted a series of investigations as to the efficiency of man as a prime mover, and made various calculations as to the amount of work that a man can do when obliged to spend his power for the driving of machinery. Later on in life he was awarded by the French Academy a prize for a theory of simple machines, and conducted an extensive series of experiments concerning the strength of materials and the friction of one body over another, either when in motion or when started from a state of more or less prolonged rest.

In connection with M. Swinden he was awarded the prize by the French Academy for the best construction of compasses.

The contribution to physical science, on which it may be said that M. Coulomb's reputation mainly rests, was the invention of the torsion balance, by means of which he conducted that extensive series of experiments in electrostatic and magnetic attractions and repulsions, which won for him a lasting reputation as an experimental philosopher of the highest type.

In the construction of the torsion balance, he established the law that the force producing the torsion of a wire is directly proportional to the angle of torsion.

It was by means of this balance that Coulomb established definitely the law that magnetic and electric attractions and repulsions between two bodies are inversely proportional to the square of the distance.

It may be of interest to the Section to note that Coulomb proposed a theory of magnetism which bears a remarkable resemblance to some of the theories of magnetism propounded during later days.

Coulomb imagined that the molecules of a magnetized bar consist of numerous separately magnetized particles, with their opposite poles in contact, and showed how the opposing actions of such poles, would, for the greater part, neutralize each other, leaving the two extreme poles alone

to act freely as centres of action at the ends of the bar. By a series of extended investigations he showed that the property of magnetism was by no means confined to iron, obtaining unequivocal signs of attraction in all of the many substances that he subjected to experiment. Nor did he ascribe this property of magnetizability to the presence of iron in the different bodies, which he found were susceptible to the magnetizing force; for, as he himself pointed out, in order to permit this supposition to be true, it would be necessary to assume so considerable a quantity of iron distributed throughout the substance, that it could not have failed to manifest itself to even ordinary chemical analysis.

Coulomb made a study of the distribution of magnetism in a magnetic needle, showing that the magnetic force is very feeble throughout nearly the entire length of the needle, but is concentrated at two points near the ends, *i. e.*, at its free poles.

It was in connection with the above studies concerning the distribution of magnetism in a needle, that Coulomb sought for an analogous distribution in an electric charge, and showed by means of his investigations that an electric charge, which is so powerful at the surface of bodies, penetrates the interior but slightly, and, at the same time, ascertained the law according to which an electric charge distributes itself over conductors of different dimensions.

His investigations also extended to the action of points on the discharge of electrified bodies.

In the domain of magnetism Coulomb constructed an improved inclination compass and proposed methods for the production of artificial magnets. He also investigated the effects which temperature produces on magnetism, calculating the temperature to which it would be necessary to heat a magnetized needle in order to deprive it entirely of its magnetism.

The brief review which I have made concerning the extended discoveries of Coulomb, when taken in connection with the translation, will, I think, show the importance of his scientific work.

THE INSTITUTE OF FRANCE.

ACADEMY OF SCIENCES.

The Perpetual Secretary of the Academy certifies that the following is an extract from the memoir of the Class of Mathematical and Physical Sciences of the National Institute of France, vol. 7, Second Semestre, p. 206:

HISTORICAL EULOGY OF CHARLES H. COULOMB.

BY M. DELAMBRE.

[*Read at the Public Séance of the 5th of January, 1807.*]

Charles Augustus Coulomb, Lieutenant Colonel in the Engineer Corps, Chevalier of St. Louis, Member of the Academy of Sciences, and afterwards of the Institute and of the Legion of Honor, one of the Inspector Generals of Education, was born on the fourteenth day of June, 1736, at Angoulême, of a family which was distinguished in the magistracy of Montpellier.

Coming at an early age to Paris, he manifested so decided a taste for the mathematical sciences that he determined to devote himself entirely to them: but, finding some obstacles to the execution of this project, he entered the Military Engineer Corps, where he at least hoped to use for his advancement that knowledge the pursuit of which was his sole passion, and, in order to achieve more promptly the end of his ambition, he determined to go to America, where he was employed by the Government in the construction of public works of the greatest importance. Here some work undertaken during hot weather seriously affected his health. The cruel malady by which he was attacked, and which had been fatal to all his co-workers, made him desirous of returning to France. His superior officer, however, kept him in the service by the higher rank to which he raised him and by inspiring hopes which were unfortunately never realized. He finally returned to France after nine years' absence. Up to this time he had given himself unsparingly to his profession. He brought to this work, as means for carrying

out with greater economy and solidity the various constructions which he directed, that spirit of experimental research and calculation which so eminently distinguished him. The observations and theories which had guided him in such work furnished materials for a memoir which he read before the Academy of Sciences, and which secured for him the title of Corresponding Member.

About the same time he designed methods for carrying on submarine works without previous drainage, and invented a species of wheel which appeared to him similar in its operation to a windmill, and tested its efficiency by comparing the useful effect with the effect lost by blows and by friction.

We would refer to this epoch a memoir, which, however, he did not publish until twenty-five years afterwards, but which he read before the Academy in 1775. In this memoir he estimated the quantity of work which men can furnish in their daily labor, according to the manner in which they employ their strength. The aim of these researches, undertaken at different epochs of his life, was to diminish the fatigue of man when obliged to act as a simple machine.

In 1779 he shared with M. Swinden the prize offered by the Academy for the best construction of compasses. Two years afterwards he carried off the prize offered by the same society for a theory of simple machines.

Amontons had published some experiments on the same subject, but these experiments, being conducted on a small scale, in the physical laboratory, were insufficient to correctly estimate the friction of machines designed to carry great loads. The first thing to do then was to design an apparatus that could be loaded with enormous weights, which would permit of variations in the trials, of the calculation of the effects, and of the observation of the friction of different bodies, either dry or covered with unguents, sliding over one another in different directions, both while in motion, or when started from a more or less prolonged state of rest. M. Coulomb who then lived at Rochefort, found in the Marine Arsenal, by the kindness of the Commandant M. Touche Treville, everything which could facilitate this

new and important research. The Academy, in crowning this work, testified their satisfaction both as to his theory and as to his experiments.

These two researches possessed that characteristic which M. Coulomb had impressed on all his works. In the one, as in the other, we observe his close attention to the interrogation of nature and his ability to seize and verify everything of importance, to search in rational mechanics for the formulæ best suited to connect the isolated facts, and to try new experiments, and, by varying them in a suitable manner, to endeavor to determine the kind of formulæ and the quantities which could be varied according to the nature of the substances submitted to experimentation.

It has already been said of those who have distinguished themselves by the advancement of new views, that the germs of their discoveries were contained in their first work; that their later productions have been but enriched and matured developments of their earlier ideas.

We have a new proof of this saying in the labors of M. Coulomb, which are to be ranked among the most advanced in physics.

In the competition for a prize on the compass, one of his competitors indicated a means for avoiding the effects of torsion; that is to say, the resistance which the suspended wire offers by its rigidity to the force of magnetism, tending to deflect the needle in a constant direction. M. Coulomb endeavored to familiarize himself with these effects of torsion, and even described at that time an apparatus for measuring with accuracy the forces of torsion, but he could not find a mechanic capable of constructing the apparatus he had designed, and this, his first conception, announced while undeveloped, no doubt contributed in some degree to the success he afterwards achieved.

There is no little difficulty in appreciating all that is contained in these first suggestions, all that was born in this early conception.

In 1781, M. Coulomb continued his labors in Paris. The Academy was eager to admit him to membership. All his thoughts were now turned toward those researches on mag-

netism and electricity which formed both his chief glory and the richest collection of the Academy. Here he completed his successive labors and discoveries.

In order justly to appreciate the services which M. Coulomb has rendered to physics, and to understand the advantages of his methods, let us take a brief glance at the state of physical science at different epochs.

The ancients were acquainted with physics in name only. To be convinced of this fact, it will suffice for one to read, if able to do so, the numerous treatises of Aristotle, not so much on the general subject of physics, as on the heavens, generation, corruption and meteors.

We will remark that in all of these are contained numerous dissertations on space, time and the principles of the elements. What advantages can one draw from this obscure mass of unintelligible metaphysics? What can we understand in the very brief treatises in which Plutarch has rendered but poor service to the Grecian philosophers, by condensing their opinions in an exceedingly brief space as if he wished by the collection the better to turn them to ridicule?

What do we see in these treatises, unless it is that, satisfied with an insufficient examination into some phenomena of nature, the authors had been afforded an opportunity of exercising their imagination on such phenomena, without being able to invent any of those ingenious machines which aid in the investigation of nature; so that with the single exception of some of the striking truths found in the writings of Archimedes concerning his inventions, together with some other of the geometricians and mechanicians of Alexandria, amongst which we find Hiero, whose name even yet is given to an interesting machine found in all cabinets of philosophical apparatus, we would be perplexed to find in their writings any statements which could properly be inscribed in modern treatises, and, if we did mention their names it would only be to point out their errors. We see then the reason for the small progress which the ancients made in physics; they only studied it as metaphysics.

The reason they had more success in the study of astronomy was because at an early date they felt the necessity for employing suitable instruments and making observations and calculations.

The happy applications of geometry to one of the most important branches of physics pointed out the road necessary to follow in order to equally perfect all other branches. It was in fact this road which Galileo took at the epoch of the revival of letters and sciences.

It was by geometry that he discovered new and ingenious means for measuring the fall of bodies.

The pendulum, the barometer, the air pump and the prism enlarged the field of experimentation. His book of mathematical principles placed physical science on a true basis. The fact was then fully appreciated that the sciences could be perfected only in so far as they could succeed in carrying into this obscure domain the double torch of experiment and calculation.

S. Gravesende endeavored to produce a complete course of mathematical physics, but magnetism and electricity could find no place in his plan; for electricity was scarcely born and magnetism had been but little developed.

Æpinus was the first who submitted these subjects to analysis. He endeavored principally to explain known effects, but his progress was inconsiderable: for he was not sufficiently careful to verify by experiments the results which he obtained by calculation.

It was by illuminating one fact by another and by fusing them into one, that M. Coulomb reached the hitherto unknown principles with which he enriched physics.

From the first he appreciated the necessity for new apparatus. Attractions, either electric or magnetic, so powerful at exceedingly small distances, either rapidly decreased or disappeared entirely at comparatively small increase of such distances. In order to measure them correctly, it was necessary to oppose them to a known force which they could readily overcome; to employ a body so light as to permit the least force to impart to it a sufficiently great movement, under conditions in which

exceedingly small forces could be rigorously measured. M. Coulomb hoped to find such a force in the almost imperceptible resistance a wire offers to a force tending to twist it. He ascertained that this resistance increases uniformly with the amount of torsion given to the wire, or, to speak in scientific language, that the force was proportional to the angle of torsion. He was then in possession of the instrument he so long desired, and it was by this simple means that he discovered the law which had hitherto escaped the researches of physicists.

He showed by simple and convincing experiments that the attractions and repulsions are in the inverse ratio of the square of the distance. This law was immediately adopted by all physicists, most of whom had a presentiment of its truth. Æpinus had often employed this law in some of his calculations, judging it to be the most probable that could be conceived, but he had not been able to discover the means for its demonstration. This glory was reserved for M. Coulomb.

These discoveries accomplished, by means of which he conquered two modern branches of physics, we see M. Coulomb employing the rest of his life in cultivating the domain he had conquered.

The law which he had discovered became of great assistance in his subsequent calculations and experiments. But it was not sufficient. It would be necessary to combine with it an intimate knowledge of the essential properties of that marvellous agency, the production of which we cannot yet entirely control. Æpinus explained the principal phenomena of electricity and magnetism on the assumption of the existence of a fluid, the molecules of which possessed the double property of mutually repelling one another, and of being attracted by the molecules of gross matter. But he was obliged to assign to these molecules the double property of mutually repelling one another and yet of being attracted by the molecules of other bodies, a property difficult to reconcile with generally received notions.

The hypothesis of a double electric fluid conceived by

Symmer, and employed by Wilke and Brougman, though less simple at first glance, nevertheless contains nothing inconsistent with well-known principles. In all his calculations M. Coulomb adopted this hypothesis as the best.

In order to place this hypothesis beyond all objection, and entirely to reconcile it to the phenomena of attractions and repulsions which it describes, it is very desirable that one should be able, by direct experiments, to demonstrate the existence of these two still problematical electric fluids. They are now indicated only by calculation. They can explain phenomena, but nothing yet demonstrates that it is impossible to find a simpler explanation of such phenomena.

When the early astronomers wished to account for the unequal movements of the sun they found two hypotheses equally capable of satisfying their observations. The double inequality in the movements of the planets requires the assumption of two hypotheses, either of which sufficed to account for the orbits of the very eccentric planets, such as Mars and Mercury. This system, which at first seemed so happily conceived, was afterwards set aside or reversed by Copernicus and Kepler.

One might fear, or indeed, rather desire, a similar fate for our two hypothetical fluids. Already we feel that the phenomena in question require further explanation. To avoid this difficulty, M. Coulomb supposes that all the molecules in a magnetized bar consist of so many magnetized parts, the opposite poles of which are in contact. The opposite actions of these poles should for the greater part destroy each other. The two extreme poles can alone act freely and hence form two centres of action placed at the extreme ends of the bar. No matter how ingenious this conjecture may be, it may very closely resemble the hypothesis of epicycles of the ancient astronomers, which possessed no other real merit than to facilitate calculations which will lead to the knowledge of the real causes. It is the same with the two electric fluids. It is very ingeniously assumed that the resinous and vitreous fluids experience unequal resistance in the air. Nothing prevents us from admitting hypotheses provided they are not incompatible with known principles,

only we may regard with regret the complexity of the system. But, in the midst of so many causes which act to obscure the phenomena, it is not astonishing that the explanation loses much of the simplicity that we would desire it to possess. The planets, separated from one another by immense distances and moving through free space, may rigorously follow the law which suffices to explain their almost imperceptible inequalities. But bodies which we hold in our hands, and with which we experiment, are very far from being placed under such favorable circumstances. Where many forces operate it is necessary to include them all in the calculation, so that complex effects would not be reduced to very simple principles. It is not, therefore, the fault of the physicists if their explanations are not characterized by that unity which we are accustomed to find in the problems of astronomy.

But if physicists are thus placed at disadvantages they are recompensed by other considerations which should animate them with courage.

The heavenly bodies revolving at such vast distances from us, only complete their revolutions in times that are more or less considerable, but always very long, and it is only at great intervals that they can come into conditions favorable for the researches of those who wish to explain their movements. The physicist, on the contrary, holds in his hands the objects of his study. He can at will place them in suitable positions, and, if astronomy has required centuries to perfect itself, we can hope that in much less time physicists will be able to reach that certainty and clearness which may reasonably be expected.

Such progress will ultimately crown the work of those, who like M. Coulomb, have not only endeavored to create new apparatus for new research, but who also avail themselves of the infinite resources that may be found in modern analysis.

By means of the torsion balance, which permitted him to measure the feeblest manifestation of magnetism and electricity, he satisfactorily determined the law according to which electricity passes and insensibly disappears, the influ-

ence which produces the effect, the humidity of the air which surrounds the conductor, and the imperfection of the supports by which they are insulated. He showed by delicate experiments that electricity, which is so powerful at the surface of bodies, becomes insensible when we penetrate the interior but slightly, and that magnetism, very feeble through almost the entire length of the needle, possesses strength in but two points near the ends, and sought to discover the law according to which electricity distributes itself along conductors or on globes of different dimensions. What can be the cause of the power possessed by points and the great effect of the electric kite (*cerf volant électrique*). From these difficult speculations, so pleasing to him, he descends to objects of practical utility. It was to obtain a better construction for the compass that he had undertaken his early researches. In proportion as he made sensible progress he endeavored to improve his more important instruments, as, for example, the inclination compass. At this time more or less complete means for producing artificial magnets were in use. By the application of his theory M. Coulomb was enabled to add increased perfection to the best of these methods.

As regards the influence of temperature on magnetism, viz: that the strength of magnetism decreases as the heat increases, he found by very convincing experiments and by the aid of a theorem of M. La Place that it would be necessary to give a needle 700° of heat in order to deprive it entirely of its magnetism.

For a long time iron had been regarded as the only body which is attracted by the magnet. M. Coulomb found some unequivocal signs of attraction in all the bodies he subjected to experiment, from which he believed that he could conclude that magnetism like electricity occurs throughout nature.

This discovery is the last he made. The task of verifying it kept him occupied up to his last moments. We find in his manuscripts some curious experiments from which it would appear that in order to attribute to iron hid in different bodies the degree of magnetism which he had observed,

we must assume that there exists uniformly spread throughout these substances a quantity of iron so considerable that it would not have failed to manifest itself under the investigations of any distinguished chemist who had undertaken to separate or purify the substances on which he had made his experiments. We shall not now study in detail Coulomb's unpublished researches. These cannot yet be properly judged by savants. We feel that this is not the place to give an extensive idea of his works. Besides, such an exposition already exists. All savants can read it in the best and most modern treatises on physics. Coulomb ranks among the first physicists of Europe. He has distinguished himself by creating a new branch of natural science and has presented in the clearest and most methodical manner all the discoveries and theories of his distinguished contemporaries. This extract, which may serve in some respects as a commentary on the doctrine of M. Coulomb, does not prevent us, however, from having recourse to the original writings for a multitude of details necessary for those who may wish to continue the work that was so sadly interrupted by his death.

For a long time it was hoped that M. Coulomb would collect in a complete treatise, in the order in which he had discovered and demonstrated them, the ideas which he had published in his numerous memoirs. His friends often asked for such a work, but the feeble state of his health gave him little hope of its completion. He preferred to add as much as he could to the sum of our knowledge. He left for the bookseller, who was to print the collection, a note as to the order in which he wished his memoirs arranged. Before beginning the printing, it will be necessary to examine his manuscripts, and to transcribe the notes which he added to them, for this will form an interesting sequel to the material which he has himself published.

We have so far presented M. Coulomb as a very distinguished savant. The man himself, however, was no less deserving of commendation; that good sense, that uprightness and severity of principle, which he manifested in all his mathematical researches, were no less strongly evinced in his moral conduct.

Sent to Brittany by the Minister of the Navy, as a Commissioner of the King, to examine some projected canals, he employed all his energy to prevent the adoption of ruinous plans. The province, recognizing that it could not induce him to accept any other mark of its gratitude, bestowed upon him a testimonial, which possessed in his eyes no other merit than that of often recalling to him the recollection of the services he had rendered and of the esteem he had gained. When the revolution came, he resigned all his public positions, among which was that of General Superintendent of the Water Supplies of France and Superintendent of the Fortifications. The first was hereditary in his very distinguished family and would otherwise have passed to his descendants.

Thus relieved of his labors he occupied himself in collecting the remnant of his fortune, of which he was able to save only a very small part. He hoped to find consolation in the Academy and in the continuation of his labors; but the Academy was suppressed. He retained his membership in the Commission of Weights and Measures, but was cut off from this shortly afterwards, and, being obliged to leave Paris by the law which expelled all the nobility, he retired with his friend Borda, to a country seat which he owned, in the neighborhood of Blois.

In this solitude, in the bosom of his family, and with the consolation of friendship, M. Coulomb almost changed the manner of his life. He was able still to continue his meditations, which he even extended to new objects. The vegetable world claimed his attention. Some trees he had cut down gave him ideas on the motion of the sap. He began some researches on plants, and the fragmentary notes on these subjects which we find in some of his manuscripts, make us wish that the remainder was accessible.

Recalled from exile to continue his labors on weights and measures, we find him at this work for but a few days. He was anxious to return to his wife and children and to take care of the little property which was now their sole resource.

He returned to Paris only on the re-establishment of the

Institute. His health, which had been impaired, made it necessary for him to seek that medical aid which he had so long refused. An excessively nervous temperament gave him vivacity of character, coupled with a certain impatience, from which however, owing to his constant endeavor to conquer it, he alone suffered.

Named as an Inspector General of Instruction, although he might have regarded this favor as an indemnification for his many losses, and although by reason of his varied knowledge in different branches of public instruction, he was as well qualified as any person for so important a post, yet he hesitated a long time as to whether he should accept it.

He feared fatigue that would injure his health, as well as protracted absence that would interrupt works in which it would be difficult to find a substitute. He had devoted himself to developing the character of a son, who already responded to his care and whom he would now be obliged to place in other hands. He however, accepted the position offered, Madame Coulomb now became his inseparable companion in all his work. Thanks to her care and to her active tenderness, he escaped the dangers he had feared from his public labors.

M. Coulomb gave himself up to his new duties with all the zeal and precision which characterized him. His grave and severe countenance was softened by the presence of young children, who recalled to his paternal heart its sweetest delight. He spoke to them as a father to his children; aided them in their weaknesses and encouraged them in their timidity. He loved to find, in their growing character, promises of talent which might eventually be of use to his country. Only those who have seen him in private life can properly testify to the charm and abandon of his nature. Faithful husband, kind brother, good father and friend, man of integrity and devoted citizen, he exercised all virtue spontaneously and without ostentation; severe to himself but indulgent toward others. His manner exhibited that ease which comported so well with the gravity of his character, but which could not suppress his

sweet and quiet gaiety which was that of a soul at peace with itself. Noble and generous in all his affairs, he occupied himself least of all with his own interests.

Although modest and unpretentious, he knew how to repel an unjust attack with both strength and dignity. This last trait of his character he had but little occasion to develop. In the one case which comes to our knowledge, and which the Institute has not forgotten, his adversary who did not know that he was attacking M. Coulomb, afterward admitted his own error.

No one enjoyed more general consideration. He had seen his doctrine admitted and taught by the most distinguished scientific men. The world was pleased to render him justice. His merit and his success never made him an enemy. He longed for nothing but better health. His condition, for a long time before his death, gave his friends much uneasiness. A grave chronic infirmity, which he himself regarded as the forerunner of approaching death, was added a slow fever which gradually consumed him.

The feeble condition to which he was reduced, forbade him taking any nourishment; and all resources of art, administered by hands of friendship, were found equally powerless to mitigate his suffering or to revive his failing strength. He died on the twenty-third of August, 1806, leaving to his son no other inheritance than his honored name, the example of his virtues and the memory of the important services which he had rendered to the world.

His place in the Academy was filled by M. Montgolfier.

Certified and confirmed by the Perpetual Secretary of the Section of Science and Mathematics. F. ARAGO.

Section of Engineers and Naval Architects

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the Preliminary Meeting of the Penn Institute of Engineers and Naval Architects as a Section of the Franklin Institute, September 21, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 21, 1893.

Mr. WM. H. BARGER, in the chair.

The Chairman appointed Mr. Newman Secretary for the evening.

Members present—Messrs. Barger, Yeo, Cresswell, Sicord, Quinn, Lovekin, Nilson, Newman, Helstrom.

Members absent—Messrs. Folmer, McLaughlin, Campbell, Ham, Pistor, Hartley, Matlack, Branson.

The Chairman stated that the gentlemen above-named as forming the Penn Institute of Engineers and Naval Architects, individually members of the Franklin Institute, had as a body made application for permission to form a Section of the Franklin Institute, to be known as the Section of Engineers and Naval Architects; that the application had been granted, and that the object of the meeting was to fix upon an evening for holding the monthly meetings and to elect officers.

He also stated that he had interviewed Dr. Wahl, the Secretary of the Institute, and had been informed that the most suitable evening would be the fourth Wednesday of each month.

It was thereupon resolved to hold the monthly meeting on that evening.

Resolved; that as the meeting consists of a majority of the members, it do now proceed to elect officers.

The following officers were then elected:

President—R. L. Newman.

Vice-Presidents—Wm. H. Barger, Andrew Ham, Wm. F. Sicord.

Recorder—Robert McLaughlin.

Treasurer—Alexander Campbell.

Corresponding Secretary—John F. Quinn.

Conservator—George S. Yeo.

The Chairman appointed the following gentlemen a committee to draft a set of by-laws for the government of the Section: Messrs. Campbell, Barger, Ham, Sicord, Folmer.

It was then resolved that the first regular meeting of the Section be held on the fourth Wednesday in October.

The meeting then adjourned. R. L. NEWMAN, *Secretary pro tem.*

[*Proceedings of the stated meeting, held Wednesday, October 25, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 25, 1893.

Mr. R. L. NEWMAN, President, in the chair.

The first stated meeting of the Section of Engineers and Naval Architects was held this evening.

The minutes of the preliminary meeting were read and approved.

The President having announced the unavoidable absence of the Recording Secretary, Mr. Campbell kindly volunteered to perform his duties for the evening.

The following gentlemen were proposed and duly elected to membership:

Messrs. Edwin S. Cramp, Lewis C. Nixon, James H. Horgan, Walter S. Cramp, J. W. Atlee, James Young, Nesbit Sinclair, G. L. Davidson, E. C. Given, E. Heyne, E. Hoel, C. Heinrichs, Nelsen Madsen, Wm. Collison, Wm. H. Wahl, John McInnes, John McMaster, John A. Nilson, Thos. Jarvis, John Sullivan, James B. Rowen, Wm. J. Warne, Leighton Lee, W. K. Watson, Albert Duboy, E. L. Peacock, John Bayne, Jr., Henry Pemberton, Jr., F. L. Gamson, R. D. Wilson, C. B. Schultz.

This being the first regular meeting of the Section, the President delivered his inaugural address, in which he dwelt upon the foundation of the Section, its aims and its prospects for the future.

The by-laws were then read, and Articles 8, 11, 13 and 14 amended.

The Section unanimously accorded a vote of thanks to Dr. Wahl, Secretary of the Institute, for his kindness in being present and for his assistance in formulating the by-laws.

Mr. Barger was accorded a vote of thanks for the energy he displayed in bringing the members together for this evening's meeting.

Attendance, thirty-three persons, including visitors.

The meeting then adjourned.

ALEX. CAMPBELL, *Secretary pro tem.*

[*Proceedings of the stated meeting, held Wednesday, November 22, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 22, 1893.

Mr. R. L. NEWMAN, President, in the chair.

The second stated meeting of the Section of Engineers and Naval Architects was held this evening.

The minutes of the previous meeting were read and approved.

The by-laws were read, with amendments made at previous meeting, and unanimously adopted.

The following-named gentlemen were proposed for membership and duly elected: Messrs. August Bod, J. V. Olsen, Jas. S. Doran, Wm. C. Foley, Thomas Jordine, Walter Whetstone, A. Masters, James C. Workman.

A paper on "The Subdivision of Steamships" was read by Mr. Andrew Ham.

An animated and instructive discussion followed the reading of Mr. Ham's paper, and was participated in by Messrs. Foley, McInnes, Stoever, Warne, Newman and Campbell.

Attendance, thirty-six persons, including visitors.

Adjourned. ROBERT MCLAUGHLIN, *Secretary.*

SECTION OF ENGINEERS AND NAVAL ARCHITECTS.

THE PRESIDENT'S INAUGURAL ADDRESS.

[*Read at the first stated meeting of the Section, held Wednesday, October 25, 1893.*]

MR. RICHARD L. NEWMAN, President, in the chair.

On assuming the chair, the President spoke as follows:

GENTLEMEN:—I take this opportunity of expressing to you my thanks for the honor you have done me in electing me your first President.

It will be my earnest endeavor during this session to promote the best interests of this Section, and, as one of its founders, I am the more anxious to see it a complete success. I trust that both the officers, and all our friends who have its welfare at heart, will support me in my endeavor to this end. I hope, therefore, that they will attend regularly at our various meetings, and thus, by their presence, encourage the contributors of papers and give to this Section (and especially to the younger members of the same) the benefit of their experience and advice. For I consider that the great feature of societies like our own is the discussion of subjects, rather than the mere listening to a paper or a lecture.

I also trust that many of our younger members will join in these discussions, both for the sake of eliciting information from those who can give it, and to show that they take an interest in the subject under discussion. A good way of learning something of a subject, is to criticise it in a proper spirit, and any young member who will get up the

necessary information to properly criticise such papers as may be read here, will find, at the end of the session, that he has gained considerable information.

I must also congratulate you on your good fortune in starting as a Section of one of the oldest scientific societies in America, if not the very oldest.

Here you have a good and permanent home and the use of one of the most complete scientific libraries in the country. The advantages of the latter must be plain to all, as it brings within the reach of those of our members who desire to prepare themselves for our future discussions, such books as would otherwise be difficult to obtain.

As to our financial position I can say but little; but I would call your attention to the necessity of accumulating funds in the early days of a society like this for its successful career afterwards—for the day must come when, to continue with success, we shall have to expend considerable sums of money; and, to enable us to do so, I would recommend economy until such time as we consider ourselves on a sound financial basis.

Another point that I would particularly draw your attention to, is this: that those of our members who are willing to provide us with papers during the present session, would greatly facilitate our arrangements by notifying the Secretary as to the subject they desire to write on, and the earliest date at which they can deliver the paper to the Secretary to enable him to arrange a syllabus of our future work. We have already received promises of papers from Mr. Walter Cramp, Mr. Campbell, Mr. Peacock, Mr. Blumberg, and several other gentlemen.

Although at one time it appeared as if mechanical engineering and ship-building had a limit to which we were fast approaching, and that sooner or later all that could be known, or was worth knowing, would become known, yet, as time goes on, we are found branching out right and left on new departures. We find that, so far from having reached the length of our scientific tether, completely new fields have been opened up. During the last eight years

the marine engine has undergone another change somewhat similar to that which it passed through some twenty to twenty-five years ago. The result of this has been further economy of fuel, and although not so startling as in changing to the first compound, yet the gain was sufficiently tangible to justify engineers in their new departure, and it has been the means of inducing men, in their hunt for a remunerative investment, to spend their money with the engineer and ship-builder. We are, I think, now at a stand-still, as far as the engine is concerned, and are likely to remain so for some time to come. It is true that we have the quadruple engine, but I think the gain, or economy, here is more apparent than real, and is likely to remain so until such time as we are in a position to command and work much higher steam pressure than we now have.

The next advance will, I think, be made in the boiler, in the apparatus in which the agent is generated for propelling the machinery. Whether it will be a steam boiler or not I cannot say; but when we look round and realize with what an extravagant hand we draw on the bountiful resources of nature, it is then, and only then, that we see the necessity for a saving in this direction. Can anyone imagine anything more crude than our modern boiler? I grant you that it has been created by the surmounting of a series of difficulties that only an engineer can appreciate; but I am now dealing with the machine as viewed from a scientific standpoint, and I am sure you will all agree with me that when we put under a boiler a certain quantity of coal, representing theoretically a given quantity of work and in return get between 0·5 and 0·7 of this theoretic value, it is then time for us to look round for another agent or a more economical method of developing the present.

Gentlemen, it is one of the easiest things in the world to find fault; but it has been my experience that it is one of the most difficult to find a remedy.

Here we are, finding fault with a very old friend, but we shall have to stick to him, or improve him, until we can find a better.

I think the future march of improvement should be

looked for in the development of the multitubular boiler, induced or improved forced draught, and the adoption of petroleum as a fuel.

In the first case, we may be able to get a boiler to generate steam at say 500 or 600 pounds per square inch, thereby increasing the indicated horse-power per ton of boiler. But it might be urged that we could not handle steam at such a pressure and temperature. Admitting this to be a fact, I am still of opinion that it would pay us to reduce the pressure to about 300 pounds, thereby superheating it and raising its efficiency.

Induced Draught.—One of the most pronounced losses of the modern boiler lies in the fact, that to obtain a good combustion you have to maintain a smoke-pipe temperature of say 600° F. This heat, apart from the fact of its maintaining a good draught, is completely lost, so far as the generation of steam is concerned. With induced draught this factor becomes eliminated, as the smoke-pipe temperature is then of small importance. You could therefore absorb this heat by passing it first through a superheater and then through a large feed heater; raising your feed, probably, to the temperature of the boiler. The only work the boiler would then have to do would be to supply the heat necessary to set the vapor free, or what is known as the latent heat.

Mr. Howden claims by his plan to have effected an economy approaching the marvellous. That the figures he published are accurate is to be doubted; but that the results he obtained are satisfactory is beyond question; and there can be no doubt whatever that by heating the air supplied to the furnace by means of the waste heat of the chimney, and by forcing it into the furnace under a pressure equal to one inch of water, a more perfect and complete combustion can be obtained than by ordinary conditions, and that the economy resulting therefrom must be considerable. There still remains the fact, however, that even with this system a quantity of heat, somewhat less to be sure than would be under natural conditions, still goes off into the atmosphere, owing to the very limited capacity of air to absorb heat.

Scientific engineers are, however, looking beyond the mere question of how best to burn coals. They are looking to what may be termed the fuel of the future; that is, petroleum or natural oil. This valuable material is being found in all parts of the world, and the only thing that astonishes me is that its introduction is so slow. Russian steamers on the Volga and Caspian have long used, with the utmost success, the waste products resulting from the manufacture of petroleum.

Weight for weight, this refuse is capable of producing twice as much steam as coal can produce. It is easily stored, and practically occupies less space than does coal; it emits no smoke; it is easily regulated, and it requires the least possible amount of attention.

Here then is a picture for us engineers to contemplate. Imagine the *Lucania* fitted up with a series of multitubular boilers, with a system of feed heating reducing the smoke-pipe temperature to a minimum and raising the feed-water to a temperature equivalent to that of the boiler, and using petroleum as a fuel. Now, here would undoubtedly result a saving in weight carried, for one ton of oil alone is about equal in effect to two tons of coal, and the weight of the boilers would be reduced. There would also be a considerable saving in the cost of labor for running the machinery, and, assuming the cost of creosote per ton to be about the same as coals, the fuel bill would be reduced by about one-half. Taking the amount thus saved in weight and cost, and expending it in larger and more powerful machinery, I see no reason why, in the near future, with a properly constructed ship, we should not cross the Atlantic at an average speed of twenty-five knots or more.

Progress in ship-building is not of necessity so rapid as that in engineering, and is seldom marked by radical departures. We find perhaps some one with more enterprise than his neighbors who will build a larger and faster vessel than usual; but a ship of a new form or of new material is seldom heard of. We do find, however, that although the forms change but slowly, and although the materials of which they are built remain practically the same, the speed of our

ocean-going steamships is steadily advancing, viz: from eighteen to nineteen and twenty knots per hour.

We have seen the steam launch of seven and eight knots develop into the torpedo boat of twenty and twenty-five knots per hour. But the mercantile cargo boat of to-day is of pretty much the same character as was her predecessor of twelve years ago.

That the electric light has taken fast hold of the mercantile and of the naval marine is not to be wondered at. Its safety, cleanliness and absence of smell and of foul air is of the utmost advantage to those whose home is limited to a narrow cabin; the long nights are thus deprived of one-half their wearisomeness and terror to the passenger by its means. The convenience of being able to start mast headlights and side lights by the mere turning of three small buttons is apparent. In the engine-room it lightens the monotony of the weary watcher and enables him to make use of his eyes to a much greater extent than is possible with the ordinary means of illumination.

Steel castings can now be had of any size, form or weight, and it is price alone that prevents their complete substitution for iron ones; but that energy and enterprise which have enabled our manufacturers to provide us with steel plates at such a price as to supersede those of iron, will, I have no doubt, surmount their present difficulties, and I am confident that we may safely look forward to the time when we shall get steel castings at such a price as will enable them to supersede cast iron for most purposes.

The commercial depression has, I hope, reached its lowest point, and there are now signs, I am glad to say, of its lifting and, I hope, eventually disappearing. When the dawn of prosperity breaks upon the ship-owner, we may hope that the ship-builder and engineer will soon feel the effects of it, and that once more our now idle machinery may be supplied with work, and busy brains find remunerative employment.

This address would hardly be deemed complete without some slight allusion, however incomplete, to the most colossal undertaking of the present century, namely, the World's

Fair. Here we have a collection of machinery the like of which have never before been seen under one roof. Electric generators of 2,000 horse-power, the Ferris wheel, the buildings themselves, all are triumphs of engineering skill.

From a spectacular point of view it stands unrivalled. The Rev. W. H. Stead, in his description, speaks of it as follows: "I have seen no picture of the abode of the blest which comes near to it in its serenity, its suggestion of the invisible holiness, its atmosphere of bliss. That it would have given 'points' to the writer of Revelations, had he seen it, was a remark which scarcely seemed profane in the presence of that mystic spectacle. Precious stones do not appeal to us Westerners as they do to Orientals, and for my part I prefer the white glory of the Hellenic architecture, transfigured by the electric light, to the blaze of all the jewels with which the gorgeous imagination of the East could deck the battlements or pave the streets of Paradise. Until I see the walls of the New Jerusalem itself, I never expect to see a dream of more exquisite loveliness than this."

I trust I have not wearied your patience by travelling over so much ground. I have given you many subjects for reflection, and, I hope, not a few on which you may favor us with a paper, and I trust that the session, as regards the number and interest of the papers that will be read, may be a success.

BOOK NOTICES.

The Chronicle Fire Tables for 1893. A record of the fire losses in the United States by States and Territories during 1892, etc. New York: The Chronicle Company, Limited. (Price, $5.)

This valuable and extensive collection of fire data (now in its eighteenth year) presents its last annual tabulations in 360 pages, royal 8vo, with the usual excellence in all respects. The need for this kind of information, especially to fire insurance companies, was never more evident than now, when the fire losses in the United States during 1890, 1891 and 1892 are shown to have been, respectively, $100,000,000, $144,000,000 and $151,500,000. The situation is becoming every year more serious and alarming. The plan of the work insures accuracy, as nearly as attainable, and since adjustments and estimates of losses are obtained always several weeks after occurrence of fires, exaggeration of losses is avoided.

The work opens with general information respecting the fires, and an analysis of causes, referring in detail to the most important, while showing the distribution of losses in the geographical divisions, also the average loss per fire, losses by exposure during the past eight years and fires caused by electric wires or lights in the period 1885–92, inclusive. The last-named cause is shown to have increased the losses from $254,595 in 1885, to $2,966,536 in 1892. The main tabulation gives an alphabetical list of classes of risks, ranging from agricultural implement factories to whalebone and rattan factories, including warehouses of various kinds, separately stated. Here are given, besides the name of the class, the number of fires, property loss, insurance loss and the causes of fire, with number of fires to each cause.

Similar tabulations show the fire losses in each State and Territory during 1892, also by classes of risks. Another extensive analysis shows the fires by causes, such as accidents, ashes, hot coals, with the number of exposures, property loss, insurance loss, insurance loss by exposure and the character of the property burned. This is much like a reversal of the main tabulation, giving views from a different standpoint, thus emphasizing the information. There is, at p. 247, a *summary* of losses from all causes in detail, followed by a showing of the various risks burned in the United States in the eighteen years, 1875–92, by principal classes; then monthly losses by fires in 1892, and much other fire data which we have not space to mention.

This admirable work shows no diminution of its remarkable energy, clearness and evident correctness. No fire insurance company should be without it, nor any lawyer, for the latter have frequently to manage cases influenced by fires. It is generally believed (whether correctly we cannot say) that times of financial stringency cause a large increase of incendiary fires. To appreciate rightly this cause of fires and its extent, is now of much importance to legal and business men.

The *Chronicle Fire Tables* form a wonderful compendium of fire data, without an equal in the world; and as a condensed history of fire losses and causes of fire during the past eighteen years (and to be continued for all coming time, let us hope), its value to society and general business is simply incalculable. N.

Continuous Current Dynamos and Motors: Their Theory, Design and Testing. With sections on Indicator Diagrams, Properties of Saturated Steam, Belting Calculations, etc. An Elementary Treatise for Students. By Frank P. Cox, B.S. New York: The W. J. Johnston Company, Limited, 41 Park Row (*Times* Building). 1893. 271 pages. Eighty-three illustrations. (Price, $2.)

This work, intended for students, treats of the theory of continuous current dynamos and motors as understood and practised in the designing room, and the methods of testing described are those of the factory testing room. The practical side of various questions treated is always kept in view, discussions having little bearing in this direction being excluded, as are also the descriptions of different machines and systems which are occasionally used as padding to fill out the pages of similar treatises.

The first four chapters present a brief review of the electrical units and the general principles of the machines, and may be considered as an introduction to the subsequent portions; the higher branches of mathematics have been avoided here, as elsewhere. Chapter V is on calculations pertaining to the magnetic circuit. Chapter VI treats of the theory of windings, losses, etc., and Chapter VII of the special points to be observed in designing motors.

In Chapters VIII, IX and X, the application of the principles developed in the preceding chapters to the design of armatures, field magnets and motors, is explained by reference to numerical problems selected with the object of covering as broad a field as possible, and of showing in what manner to make the various compromises always found expedient or necessary in practical designing.

In Chapter XI and XII, the methods of testing completed machines and investigating their characteristics and the effect of various changes in design and operation are fully discussed and illustrated by numerous curves.

As the steam engine, and its efficiency have an ultimate relation to the efficient operation of dynamos and motors, the last two chapters are devoted to the subjects of indicator diagrams and steam-power calculations, which are treated in the same eminently practical manner as the electrical portion of the work. There are four appendices treating of physical tests of irons, ampère time tables, determinations of sizes of wire for armatures and field coils, and on the calculation of belt driving.

The engravings appear to be new, and nearly all of the numerous curves are said to be reproductions of those obtained in actual commercial tests. The book is a valuable addition to electrical literature. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, November 15, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 15, 1893.

Mr. JOSEPH M. WILSON, President, in the chair.

Present, 126 members and twenty-four visitors.

Additions to membership since last report, twenty-four.

The Actuary reported the following resolution, adopted at the stated meeting of the Board of Managers, held Wednesday, November 8, 1893, viz:

Resolved; that in view of the facts, that the general feeling of those who have been spoken to on the subject is that the probability of a financially successful exhibition being held at the present time is doubtful, and that the Institute in its present financial condition can assume no risks, and would therefore be obliged to obtain a large guaranty fund to guard it against loss, which fund, in the present depressed condition of business, it is feared, would be very difficult to obtain; and, further, that the question

of location and buildings essential for success forms a serious obstacle—therefore, it is the sense of the Board that it is not advisable to attempt to hold an exhibition in the year 1894.

The resolution was accepted.

Mr. C. John Hexamer concluded his descriptive account of the World's Fair.

Mr. David Branson read a paper on the subject of "Refrigeration from Central Stations," with special reference to the system of the International Cooling Company of New York, which has been for several years in successful operation in the cities of Denver, Col., and St. Louis, Mo. The paper was illustrated by a number of lantern views, exhibiting the details of the pipe line, service pipes, interior distribution, etc. (Referred for publication.)

The Secretary read a brief paper, communicated from London, England, by Mr. F. E. Ives, discussing the claims and merits of certain improvements made by the brothers Lumière on Professor Lippmann's method of color photography. (Referred for publication.)

The Secretary, in his monthly report, apropos to Mr. Ives' paper, gave some account of recent progress that had been made in the solution of the problem of photography in color. He referred also to the admirable record made by the Intramural Elevated Electric Railway in the World's Fair grounds. This road, under conditions of extreme severity, had given smooth, regular and punctual service during the entire period of the Fair, during which time it had carried more than 6,000,000 paying passengers without a single accident. While the data of the cost of its operation were not yet available, he believed that it would compare very favorably with those of the elevated steam roads in New York and elsewhere, while in respect of freedom from smoke, and the dropping of ashes, sparks and oil, it exhibited decided superiority.

Under the head of new business, the question of the advisability of holding an exhibition of type-writing machines was, on Mr. Eldridge's motion, referred to the Board of Managers for consideration.

Adjourned.

WM. H. WAHL, *Secretary*.

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU

T. F. TOWNSEND, WEATHER BUREAU, L. F. O. IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR OCTOBER, 1893.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 31, 1893.

GENERAL REVIEW.

October's normal temperature and rainfall is about 49°.7 and 3'47 inches. The present month has been 3° warmer than the average, and the rainfall a quarter of an inch less.

The warmest period was between the 9th and the 11th, and the coldest occurred during the last three days of the month, when killing frosts were general throughout the State.

The centre of the cyclonic storm of the 13th and 14th passed nearly due north over the central portion of the State, attended by high winds and heavy rains. A large amount of damage was done at various points to buildings, fruit and shade trees, fences and telegraph poles.

The *Philadelphia Record*, of the 14th, says: "Ample warning of the approach of yesterday's storm was given by the Weather Bureau. One such timely notification is well worth the amount of cost of the weather observation service." Heavy and general rains occurred during the month, on the 4th, 7th, 13th, 14th, 23d, 27th and 28th.

From January 1, 1893, to October 31, 1893, the deficiency in temperature was, at Philadelphia, 282°; Pittsburgh, 401°, and York, 364°.

For the same period the deficiency in precipitation was, at Philadelphia, 2'61; York, 7'24; and excess at Pittsburgh, 1'58 inches.

Monthly Summary of Reports by Voluntary Observers of the

County.	Station.	Elevation above Sea Level (feet).	Barometer Reduced to Sea Level.			Temperature.								
							Maximum.		Minimum.				Daily	
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Mean.	Greatest.	Date.
Allegheny,	Pittsburgh, A,	820	30·09	30·53	29·17	55·0	86	11	29	31	65·6	45 3	20·3	39	3
Berks,	Hamburg,	380	. .	. .	. .	54·8	80	9	23	31	64·9	44·8	20·1	38	9, 1
Berks,	Reading, A,	280	. .	. .	. .	52·6	. .	. .	. .	. .	. .	. .	. .	. .	. .
Blair,	Altoona, B, (28 days),	1,181	. .	. .	. .	55·6	75	10	33	31	64·0	47·3	16·7	29	9
Blair,	Blue Knob, A,	2,500	. .	. .	. .	49·2	70	9, 11	18	31	53·5	42·8	19·7	31	2
Blair,	Hollidaysburg,[1]	947	. .	. .	. .	51·3	80	9	17	31	64·6	38·4	26·2	50	2
Bradford,	Wyalusing,	718	30·11	30·51	29·19	50·7	80	10	22	31	62·0	39·4	22·6	48	11
Bradford,	Le Roy,	1,400	. .	. .	. .	52·0	78	11	24	31	61·3	42·7	18·6	37	11
Bucks,	Forks of Neshaminy[1] (30 days),	304	. .	. .	. .	53·4	. .	. .	. .	. .	. .	. .	. .	. .	. .
Bucks,	Quakertown,[1]	536	30·13	30·54	29·29	52·5	73	9	21	31	63·7	42·0	21·7	37	18
Cambria,	Johnstown, A (20 days),	1,184	30·14	30·60	28·92	54·9	85	11	. .	. .	69·7	40·1	29·6	. .	. .
Cameron,	Emporium, A,	1,050	30·12	30·62	29·09	52·0	79	11	24	31	63 8	40·3	23·0	44	11
Carbon,	E. Mauch Chunk,	330	. .	. .	. .	52·8	80	9	20	31	63·1	42·6	20·5	40	18
Centre,	State College— Agricultural Experiment Station,	1,191	30·05	30·52	29·11	52·2	79	8	21	31	61·4	40·9	20·5	39	8
Chester,	West Chester,[1]	455	30·10	30·49	29·25	54·8	81	9	28	31	63·7	46·9	16·8	30	17
Chester,	Coatesville,[1]	380	. .	. .	. .	53·3	91	9	22	31	67·7	42·6	25·1	47	9
Chester	Kennett Square, A,	275	. .	. .	. .	55·8	84	9	22	31	66·8	44·8	22·0	37	9,
Chester,	Phœnixville, A,	190	30·17	30·56	29·30	55·7	83	9	25	31	65·5	45·9	19·6	36	9
Chester,	Westtown (28 days),	330	. .	. .	. .	54·0	80	10	18	31	63·6	44·5	19·1	32	10
Clearfield,	Grampian (30 days),[*1]	1,450	. .	. .	. .	49·5	76	11	18	31	60·0	40·9	19·1	44	2
Clinton,	Lock Haven,[1]	560	. .	. .	. .	52·4	83	9	22	31	66·7	39·4	27·3	47	2
Columbia,	Bloomsburg, A— State Normal School,	500	30·05	30·43	29·49	53·3	79	9	24	31	63·8	42·8	21·0	35	2
Crawford,	Meadville— Divinity Hall,[1]	1,200	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Crawford,	Saegertown, A,	1,700	. .	. .	. .	50·8	88	20	20	31	61·5	36·0	29·5	51	11
Cumberland,	Carlisle[1] (19 days),	480	. .	. .	. .	53·6	85	9	23	31	66·7	42·4	24·3	40	9
Dauphin,	Harrisburg, A,	361	30·13	30·52	29·26	55·0	82	9	28	31	63·0	47·0	16·0	32	9
Delaware,	Swarthmore, A— Swarthmore College,	190	30·11	30·44	29·29	56·5	80	9	27	31	64·9	48·2	16·7	29	17
Erie,	Edinboro,[*1]	1,400	. .	. .	. .	50·4	76	11	24	31	. .	. .	. .	. .	. .
Erie,	Erie, A,	681	30·05	30·50	29·05	54·0	84	12	30	31	62·0	46·0	16·0	28	2
Fayette,	Uniontown[1] (26 days),	1,000	. .	. .	. .	56·2	81	12	29	17	66·7	45·7	21·0	35	2
Franklin,	Chambersburg[2] (29 days),	618	. .	. .	. .	54·4	80	9	28	30, 31	62·9	45·8	17·1	40	9
Fulton,	McConnellsburg,[1]	875	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Huntingdon,	Huntingdon, A— The Normal College,	650	. .	. .	. .	52·5	82	9	21	31	66·4	33·7	27·7	44	2
Indiana,	Indiana— State Normal School,	1,350	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Juniata,	Kilmer,[*2]	475	. .	. .	. .	53·9	75	24	28	31	. .	. .	. .	. .	. .
Lancaster,	Lancaster, A— Franklin and Marshall College,	413	30·14	30·51	29·27	54·3	82	9	24	31	64·7	43·9	20·8	36	18
Lawrence,	New Castle,[1]	932	. .	. .	. .	52·3	82	11, 12	19	31	63·5	35·6	27·9	45	2
Lebanon,	Lebanon, A,	458	30·14	30·52	29·08	53·3	80	9	22	31	64·4	42·2	22·2	38	9
Lehigh,	Coopersburg,[1]	520	. .	. .	. .	53·2	75	9	25	31	61·4	45·7	15·7	31	17
Luzerne,	Drifton (26 days), A,	1,683	30·19	30·57	29·24	51·8	76	11	22	30	64·7	39·0	25·7	38	2, 4
Luzerne,	Wilkes-Barre, A,	575	. .	. .	. .	53·2	82	9	21	31	66·2	41·3	24·9	43	11,
McKean,	Smethport, A,	1,500	. .	. .	. .	50·5	81	11	17	31	63·6	37·5	26·1	50	11
Montgomery,	Pottstown,	150	. .	. .	. .	55·5	81	9	27	31	63·4	45·7	19·7	36	9
Montgomery,	Skippack, A (25 days),	. .	. .	. .	. .	54·5	88	24	25	31	66·7	42·3	24·4	37	9
Northampton,	Easton[1]— Lafayette College,	325	. .	. .	. .	53·0	75	9	24	30	61·5	43·9	18·3	28	9,
Perry,	(Aqueduct) Logania,[*1]	367	. .	. .	. .	55·8	80	9	22	31	66·1	44·6	21·5	37	9
Philadelphia,	U. S. Weather Bureau, A,	117	30·12	30·53	29·31	58·0	80	9	31	31	65·4	49·9	15·5	26	1
Philadelphia,	1529 Centennial Avenue, A,	190	30·12	30·53	29·31	57·4	80	9	30	31	65·6	49·2	16·4	26	1
Philadelphia,	3911 Locust Street, A,	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Pike,	Blooming Grove,[*1]	. .	. .	. .	. .	49·4	76	11	20	30, 31	. .	. .	. .	. .	. .
Schuylkill,	Girardville[1] (29 days),	1,000	30·05	30·45	29·16	52·1	78	9, 9	28	31	69·3	43·9	19·1	36	9
Snyder,	Selins Grove, A,	455	30·07	30·43	29·23	52·4	75	9	26	30, 31	67·1	37·7	29·4	41	1
Somerset,	Somerset, A,	2,250	. .	. .	. .	49·2	81	10	18	31	63·4	38·7	24·7	42	11
Tioga,	Wellsboro,[*1]	1,397	. .	. .	. .	46·0	74	9	20	31	58·1	33·3	21·8	41	2,
Union,	Lewisburg, A,	450	30·12	. .	. .	52·6	82	9	22	31	64·6	40·6	24·0	45	2
Warren,	Columbus,	1,410	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Wayne,	Dyberry,[1]	1,100	. .	. .	. .	48·1	79	9	15	31	61·8	37·4	24·4	49	1
Wayne,	Honesdale,[1]	1,000	. .	. .	. .	50·2	73	9	19	13	60·0	40·5	19·5	34	1
Wayne,	(Salem Corners) Hamlinton,[1]	1,600	. .	. .	. .	48·7	76	12	19	31	60·9	40·5	20·4	38	1
Westmoreland,	(Immel Reservoir) Lycippus,[*1]	1,200	. .	. .	. .	55·6	86	11	35	30	. .	. .	. .	. .	. .
Westmoreland,	Ligonier,	1,750	. .	. .	. .	51·5	87	11	18	31	66·0	37·4	28·6	53	1
Wyoming,	South Eaton, A,	660	. .	. .	. .	52·0	79	9	21	31	69·4	41·5	20·9	39	1
York,	York, A,	385	30·07	30·48	28·99	54·2	82	9	29	31	65·0	43·4	21·6	40	.

A, Observations taken at 8 A. M. and 8 P. M. B, Observations taken at 12 Noon. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 + 4.

HE PENNSYLVANIA STATE WEATHER SERVICE FOR OCTOBER, 1893.

ILY RANGE.			Relative Humidity.	Dew Point.	PRECIPITATION.				NUMBER OF DAYS.			WIND.			Observers.
												PREVAILING DIRECTION.			
Date.	Least.	Date.			Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	7 A. M.	2 P. M.	9 P. M.	
3	5	15	72·9	44·6	3·22	. . .	. . .	10	17	4	10	SE	SE	SE	O. D. Stewart, Weather Bureau
9, 17	3	4	. . .	. . .	3·57	. . .	. . .	6	10	14	7	E	. . .	. . .	William Shipe.
. . .	. . .	. . .	. . .	. . .	3·18	. . .	. . .	10	. . .	. . .	. . .	. . .	. . .	. . .	Franklin Yager.
9	5	23	. . .	. . .	2·72	. . .	. . .	10	. . .	. . .	. . .	. . .	. . .	. . .	Dr. C. B. Dudley.
2	2	15	. . .	. . .	6·58	T	. . .	11	11	10	10	NW	NW	NW	A. H. Boyle.
2	10	15, 23	. . .	. . .	3·93	. . .	. . .	9	16	9	6	W	W	W	Prof. J. A. Stewart.
11	3	24	85·0	46·3	1·33	. . .	. . .	6	15	2	14	S	NW	NW	Charles Beecher.
11	3	23	. . .	. . .	3·91	T	. . .	10	11	10	10	SW	SW	SW	G. W. T. Warburton.
. . .	. . .	. . .	. . .	. . .	3·35	. . .	. . .	9	19	10	8	W	E	E	J. C. Hilsman.
28	7	4	82·9	47·1	3·33	T	. . .	7	14	11	6	NW	NW	NW	J. L. Heacock.
. . .	. . .	. . .	. . .	. . .	3·22	T	. . .	11	9	14	8	S	. . .	S	E. C. Lorentz.
11	6	15, 30	91·7	44·7	3·36	T	. . .	12	13	5	13	NW	. . .	E	T. B. Lloyd.
28	3	4	. . .	. . .	2·94	. . .	. . .	7	13	10	8	E	E	E	F. C. Wintermute.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
8	6	23	75·3	44·1	3·23	. . .	. . .	10	11	7	13	S	S	S	Prof. Wm. Frear.
17	5	4	73·0	47·0	3·45	. . .	. . .	9	10	4	8	NW	E	E	J. C. Green, D.D.S.
9	6	4	. . .	. . .	4·08	. . .	. . .	9	16	6	9	W	W	W	W. T. Gordon.
9, 17	6	4	. . .	. . .	2·37	. . .	. . .	10	19	2	10	NW	. . .	NW	B. P. Kirk.
9	5	4	79·7	47·4	3·49	. . .	. . .	10	11	7	13	NW	. . .	NW	Knowles Croskey.
10	6	5	. . .	. . .	. . .	. . .	. . .	6	15	8	5	W	. . .	W	Harry Alger.
2	2	15	. . .	. . .	2·62	. . .	. . .	6	12	11	7	W	W	SW	Nathan Moore.
2	5	4	. . .	. . .	2·67	. . .	. . .	9	16	5	10	W	W	W	Prof. J. A. Robb.
2	9	16, 29	81·8	46·2	1·18	. . .	. . .	8	14	8	9	W	. . .	N	Prof. J. G. Cope.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Chas. Graves.
11	7	15	. . .	. . .	3·00	0·2	. . .	8	13	9	9	S	. . .	SW	J. G. Apple.
9	6	4, 28	. . .	. . .	·97	. . .	. . .	4	11	4	4	Calm.	SW	W	J. E. Pague.
9	4	4	82·0	48·0	3·25	. . .	. . .	9	13	7	11	W	W	W	F. Ridgway, Weather Bureau.
17	5	23	84·0	49·0	3·35	. . .	. . .	4	11	13	7	NW	. . .	NW	Prof. Susan J. Cunningham.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	17	4	10	W	. . .	. . .	C. F. Sweet.
3	4	27	70·0	49·0	3·84	. . .	. . .	10	12	7	11	S	S	S	P. Wood, Weather Bureau,
2	5	15	. . .	. . .	3·22	. . .	. . .	6	17	3	6	SW	SW	SW	Wm. Hunt.
9	2	5	. . .	. . .	3·85	. . .	. . .	5	19	3	7	NE	SW	SW	G. W. Ludwig.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	T. F. Sloan.
2	10	15	. . .	. . .	3·70	. . .	. . .	8	15	3	13	W	. . .	W	Prof. W. J. Swigart.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. S. C. Schmucker.
. . .	. . .	. . .	. . .	. . .	4·41	. . .	. . .	7	13	8	10	W	. . .	. . .	R. J. Mickey.
18	6	4	86·0	48·3	3·30	. . .	. . .	9	19	4	8	W	. . .	W	W. E. Bushong.
2	7	15	. . .	. . .	4·59	. . .	. . .	8	13	5	13	SE	S	SW	Wm. T. Butz.
9	8	4	91·4	48·4	3·95	. . .	. . .	8	14	10	7	NW	. . .	NW	G. W. Hayes, C.E.
17	2	4	. . .	. . .	3·26	. . .	. . .	10	14	9	8	NE	SW	NE	Dr. M. H. Boye.
2, 27	7	4	79·0	47·0	3·36	. . .	. . .	4	15	6	5	. . .	. . .	. . .	J. R. Wagner.
11, 12	7	15	. . .	. . .	1·70	. . .	. . .	6	16	6	9	W	. . .	W	A. W. Betterly.
11	6	4	. . .	. . .	3·65	9·0	. . .	6	11	6	14	SW	. . .	SW	Armstrong & Brownell.
9	4	4, 23	74·6	44·6	3·13	T	. . .	6	23	2	6	NW	W	E	Charles Moore, D.D.S.
9	6	23	. . .	. . .	2·30	. . .	. . .	4	14	6	5	W	. . .	W	B. W. Dambly.
9, 17	6	23	. . .	. . .	2·62	. . .	. . .	5	. . .	. . .	. . .	. . .	. . .	. . .	J. W. Moore.
9	3	27	. . .	. . .	3·29	. . .	. . .	11	16	7	8	NW	. . .	. . .	Richard Callin.
17	4	16	73·0	46·0	3·32	. . .	. . .	9	13	10	8	NW	NW	NW	L. M. Dey, Weather Bureau.
17	5	4	77·0	47·0	3·56	. . .	. . .	9	15	9	7	. . .	. . .	. . .	John Comly.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Ralph L. Paddock.
. . .	. . .	. . .	. . .	. . .	1·51	. . .	. . .	5	. . .	. . .	. . .	. . .	. . .	. . .	John Grathwohl.
9	7	16	. . .	. . .	3·87	. . .	. . .	8	14	11	4	W	NW	NW	E. C. Wagner.
2	12	23	91·8	47·5	4·91	. . .	. . .	8	3	21	7	SW	. . .	SW	J. M. Boyer,
10	10	15, 24	96·3	47·5	3·02	. . .	. . .	7	13	. . .	18	NW	SW	NW	W. M. Schrock.
2, 18	1	4	. . .	. . .	2·88	1·0	. . .	9	11	8	12	S	. . .	S	H. D. Deming.
9	7	15	92·0	48·6	3·90	. . .	. . .	10	10	10	11	S	. . .	S	Prof. W. G. Owens.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Wm. Loveland.
11	2	23	. . .	. . .	2·17	T	. . .	5	11	12	8	NW	NW	NW	Theodore Day.
18	4	23	. . .	. . .	1·99	. . .	. . .	6	. . .	. . .	. . .	. . .	. . .	. . .	John Torrey.
11	5	23	. . .	. . .	2·70	. . .	. . .	7	11	11	9	W	SE	W	T. B. Orchard, M.D.
. . .	. . .	. . .	. . .	. . .	2·92	. . .	. . .	9	. . .	. . .	. . .	. . .	. . .	. . .	Murray Forbes.
11	4	14	. . .	. . .	2·98	. . .	. . .	5	20	. . .	11	. . .	. . .	. . .	J. T. Ambrose.
11	6	4	. . .	. . .	1·88	. . .	. . .	9	12	7	12	NW	. . .	NW	B. M. Hall.
9	7	14	86·1	48·8	3·03	. . .	. . .	6	18	5	8	NW	. . .	NW	Mrs. L. H. Grenewald

[1] Mean of 8 + 8 + 2. [2] Mean of 7 + 7 + 2. Absence of numerals indicates that mean of temperature is from maximum and minimum readings.

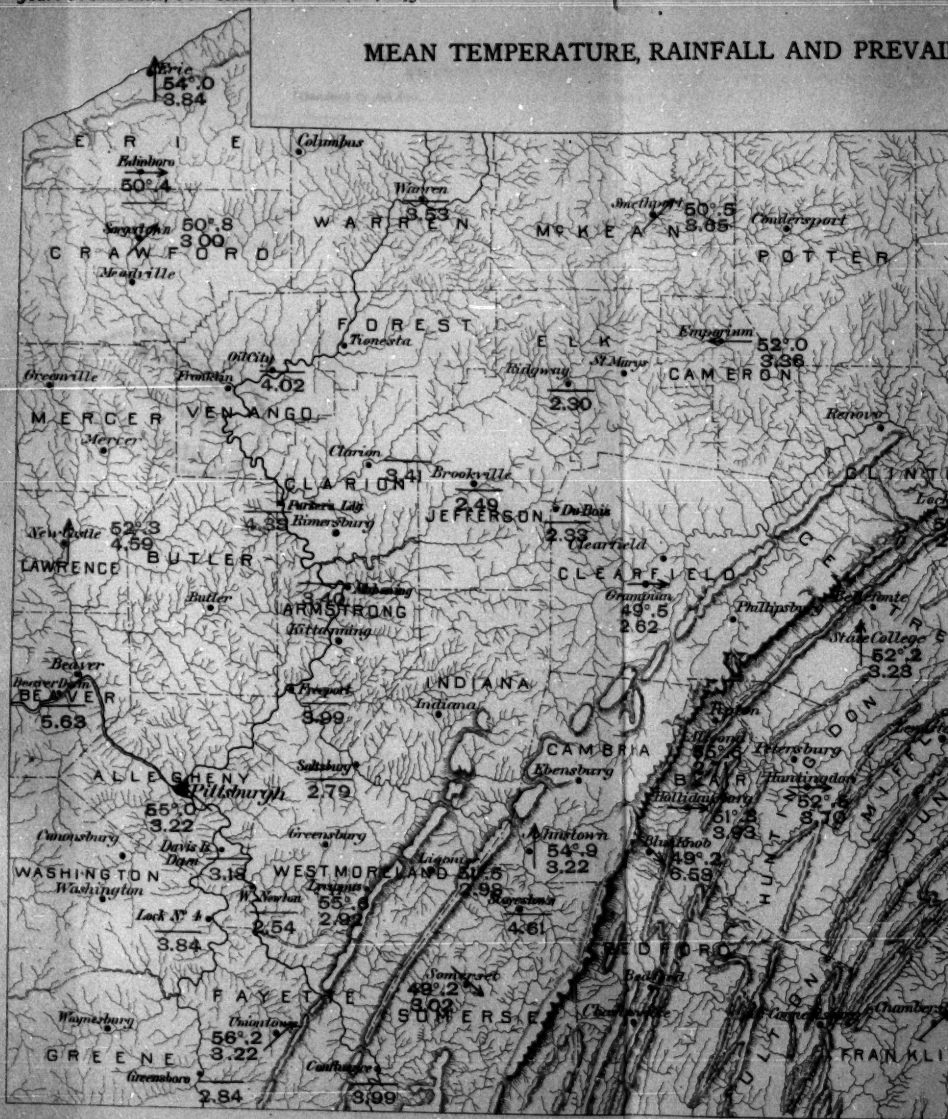
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Blooming Grove,				.02			.24							.14										.62				.49				1.51
Browers Lock,					.05		.16						.40	1.00										.18				.59				3.42
Coatesville,				.08		.06							1.80	.19								.16	.57	.18			.77	.27				4.08
Coopersburg,				.03		.04	.24						.67	.75								.09	.54	.01			.50	.31				3.26
Doylestown,							.14						.39	.61									1.33				.03	.44				2.94
Dyberry,							.26						.65	.38									.55				.33					2.17
Easton,					.05		.30							.86										.60				.81				2.62
Forks of Neshaminy,				.10			.30						.35	.48								.10	1.47	.02			.09	.54				3.35
Frederick,				.05			.13						.30	.58								.10	.66				.40	.23				2.45
Hamburg,				.28		.32							.82	.87									.55				.73					3.57
Honesdale,					.07								.89		.05								.37				.40		.01			1.99
Kennett Square,				.08		.03	.19						.45	.03								.24	.96	.02			.26	.31				2.57
Lansdale,							.09						1.14	.23									1.35				.80					3.71
Mauch Chunk,							.45						.46	.02									.74	.10			.36	.21				2.54
Ottsville,				.04			.26						.50	.60									.94	.02			.22	.50				3.08
Philadelphia, a†				.02			.56						.14	.21								.15	1.12	.01			.27	.14				3.32
Philadelphia, b,				.02		.01	.38						.23	.49								.22	1.44				.32	.45				3.56
Phœnixville,				.06			.13						.42	.94								.18	1.02	.03			.24	.46	.01			3.49
Point Pleasant,							.38						.41	.60								.05	1.23	.02			.15	1.24				4.08
Pottstown,				.05		.10							1.63									.53	.33				.39					3.23
Quakertown,				.09		.07	.17							1.35								.05	.68					.32				3.33
Reading,				.14		.01	.13						.75	1.23									.40	.01			.30	.16	.01			3.18
Salem Corners,					.07		.22							1.58		.06							.40	.09				.28				2.70
Seisholtzville,			.14										.77	.01					.02				.78				.45	.44				3.19
Skippack,						.33				•	•		1.13	.01									1.03			•	.45					8.50
Smith's Corner,				.02			.35						.39	.69								.03	1.83				.18	1.09				4.32
Swarthmore,				.10			.30																3.00				.05					3.35
West Chester,				.04		.08	.10						1.15	.31								.30	1.04				.15	.28				3.45
Westtown,																																
Susquehanna Basin.																																
Altoona,				.72	.02									1.40	.04	.09					.19		.02	.03			.05	.22				2.71
Aqueduct,																																
Bloomsburg,				.11		.02	.09									.01					.07		.51				.22	.15				1.18
Blue Knob,				.07		.07							1.97	1.44	•	•	•	•	•	•	•	.48	.22	.53	.60	•		.43	.07				6.58
Carlisle,				.60			.20								•	•							•	•				.11	.06	•			.97
Drifton,	•						•							.98	•			.38					•	1.30					.70	•			3.36
Emporium,				.80		.05	.31						.31	1.16	.12	.11							.01	.01			.35	.09	.04			3.36
Gettysburg,				.16	.58		.06						1.90										.93	.03				.34				4.00
Girardville,				.10		.18	.10						1.38	1.23	•								•	.44			.36	.18				3.87
Grampian,				1.02		.24							.38	.62								.20					.26					2.08
Harrisburg,†				.54			.14						.55	.75								.06	.63	.07			.32	.17				3.25
Hollidaysburg,				.72			.04						1.46								.26	.09	.13				.42	.08				3.93
Huntingdon,				.09									.50	1.31								.15	.20	.06		.09	.30					3.70
Kilmer,				.40									2.90	.95						.05			.10	.42			.29					4.41
Lancaster,				.17		.03	.08						.96	.92									.07	.64	.07		.36					3.30
Lebanon,				.30			.15						.55	1.82									.56	.15			.29	.13				3.95
Le Roy,				.20									.15	2.60	.10	.01							.17	.08			.15	.42	.03			3.91
Lewisburg,				.19		.07	.04						.20	1.45						.20		.35	.17				.36	.12				3.20
Lock Haven,				.24	.03								.77	.78									.16	.16			.22	.30	.01			2.67
Selins Grove,							.11						.11	1.85								.07	.11	.72			.22	1.02				4.21
South Eaton,				.12	.02		.12						.15	.60										.45	.02		.25	.13				1.88
State College,				.58									.73	1.14	.01							.04	.01	.15	.02		.48	.07		.15		3.23
Wellsboro,				.10									.08	1.95	.10									.05	.05		.15	.25		.15		2.88
Wilkes-Barre,				.08			.11							1.14														.15	.21	.01			1.70
Wyoax,				.33									1.38	.02									.11			.16	.45					1.33
York,				.44			.08					.76	1.13									.06	.34				.08	.12				3.03

†U. S. Weather Bureau Stations. • Missing.

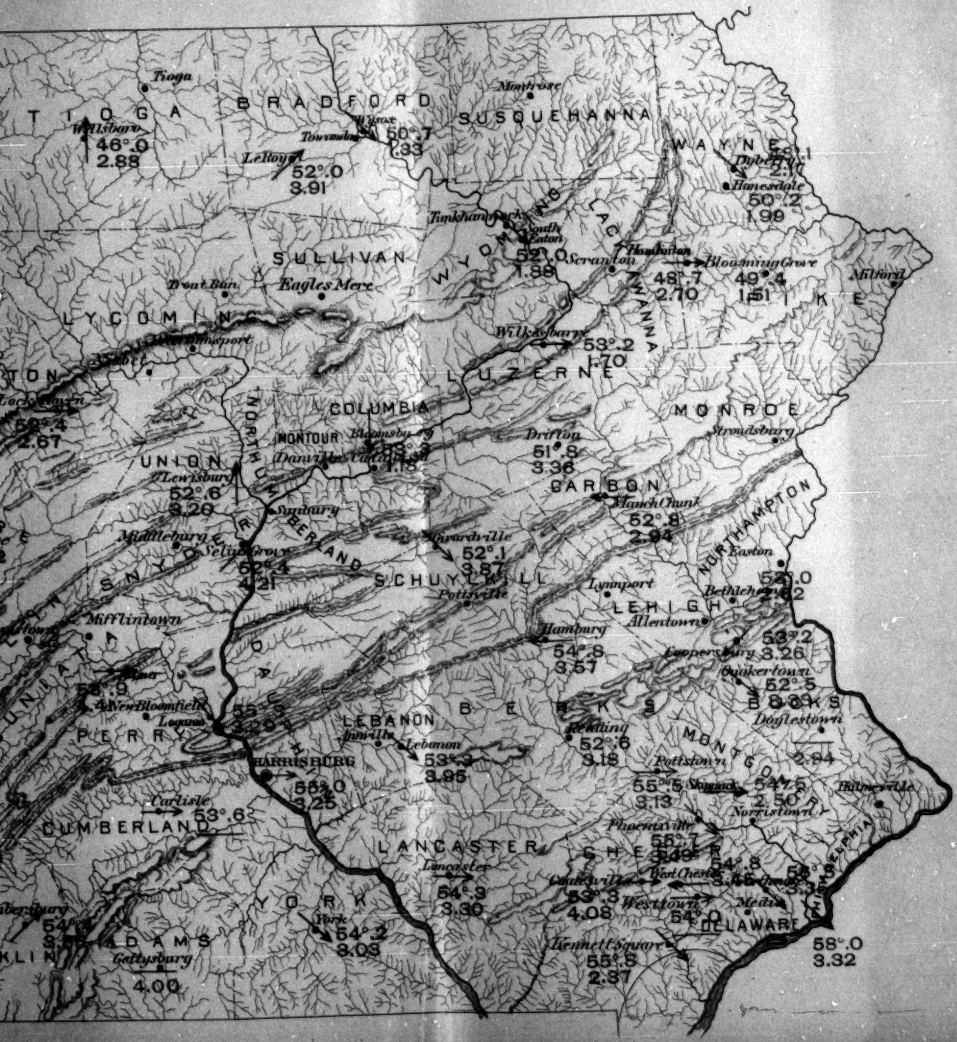
RING OCTOBER, 1893.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,	·02			·79			·40						3·44	·14							·11					·20	·13	·40			5·63
Brookville,				·79	·12		·21						·54	·47	·07									·03		·11	·14		·01		2·49
Clarion,				1·03	·07		·05						1·12	·30	·12						·05					·20	·37	·05	·05		3·41
Columbus,																																
Confluence,				1·22	·09		·01						1·16	·35							·67		·05	·05			·02	·32	·05			3·99
Davis Island Dam,	·05			·73			·04						1·58	·13							·30			·01			·11	·19	·04			3·18
DuBois,				·66			·39						·38	·38	·09									·03			·11	·24	·05			2·33
Freeport,	·11			·80	·06		1·18						1·02	·07	·03						·28						·22	·17	·05			3·39
Greensboro,	·02			·82	·08		·06						·35	·31							·30			·05			·10	·50	·05			2·84
Immel Reservoir,				·86			·55						·80							·45			·03	·03			·08	·30	·02			2·92
Indiana,																																
Johnstown,				·82									·55	·82	·04	·02					·40		·03	·07			·29	·10	·08			3·22
Ligonier,				1·08									·80	·90													·50	·40				2·98
Lock No. 4,	·02			·78	·10		·33						1·84	·19							·39						·09	·08	·02			3·44
Mahoning,				1·11	·08					·10			·98	·39	·03						·19			·03			·18	·24	·06	·01		3·40
Meadville,																																
New Castle,				·75									2·63							·15			·20				·73	·13				4·39
Oil City,				·94	·01		·07						1·45	·90	·30						·09						·79	·17	·07	·03		4·00
Parker's Landing,				·95	·09								1·87	·40	·10						·30			·01	·01		·20	·39	·06			4·38
Pittsburg,†	·02			·71		·20							1·01	·33	·05					·42				·01			·33	·14				3·22
Ridgway,			·61	·04		·20							·82	·40												·09	·09		·05			2·30
Saegertown,				·09									·21	1·02	1·22											·33	·09	·06	·05			3·00
Saltsburg,				1·00	·08		·44							·37	·24						·27			·02			·07	·24	·06			2·79
Smethport,				·45									1·75	·50	·25												·50			·20		3·65
Somerset,				1·12									·40	·42						·50	·05		·10				·43					3·22
Stoyestown,					·91	·29	·39							·96	·37	·14				·75			·12	·09				·05	·51	·03		4·61
Uniontown,				1·12			·04						·24	·48							·79					·55	*	*	*	*		3·22
Warren,				·78	·09		·01							1·14	·54	·14								·01			·43	·30	·06	·08	·01	3·53
West Newton,	·07			·77	·15		·26							·64	·14						·90			·03			·05	·21	·02			2·54
Potomac Basin.																																
Chambersburg,				·56									1·96				•			·50			·28			·53	•				3·85
McConnellsburg,																																
Lake Basin.																																
Erie,†				·69			·05					·68	1·62	·20												·02	·37	·06	·04	·11		3·84

MEAN TEMPERATURE, RAINFALL AND PREVAI



AILING WIND DIRECTION FOR OCTOBER. 1893



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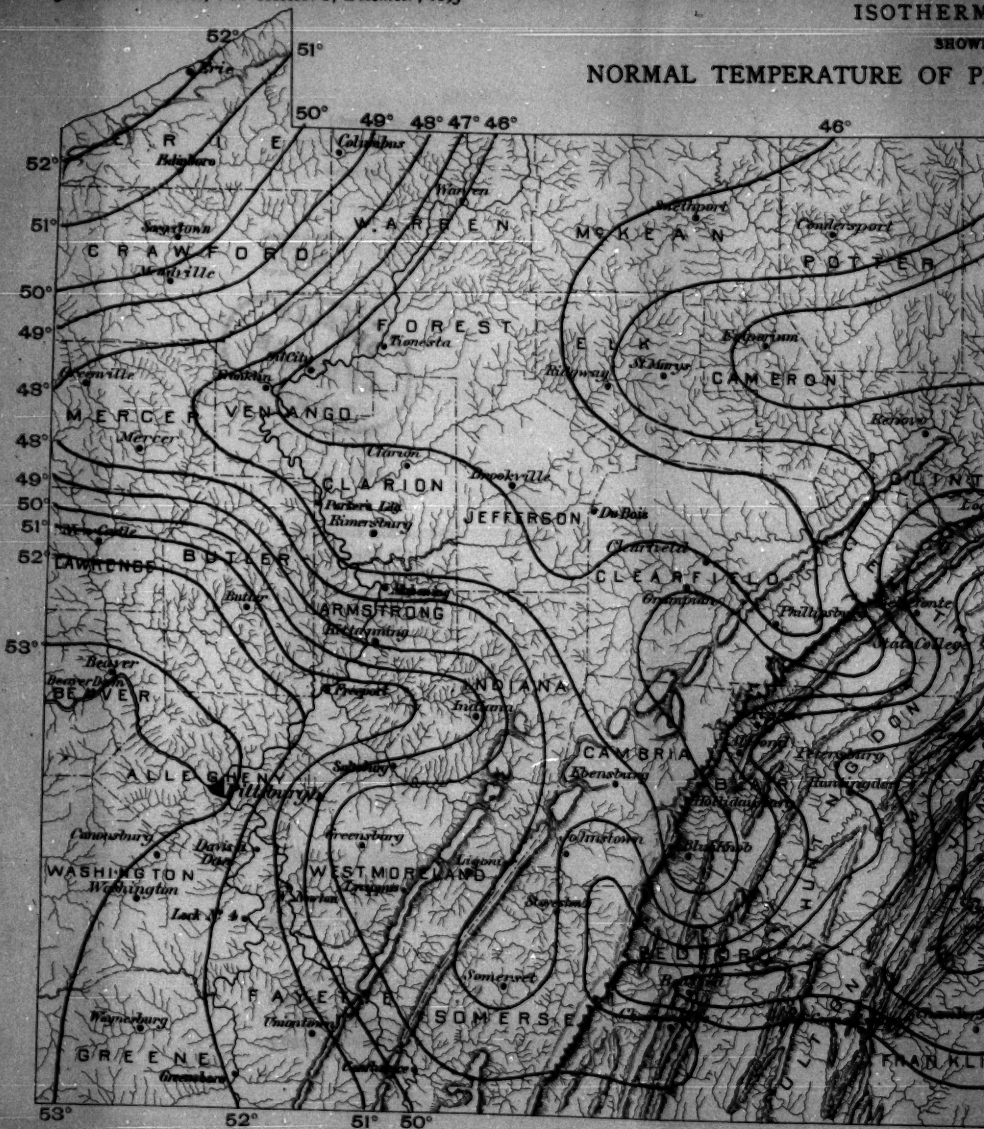

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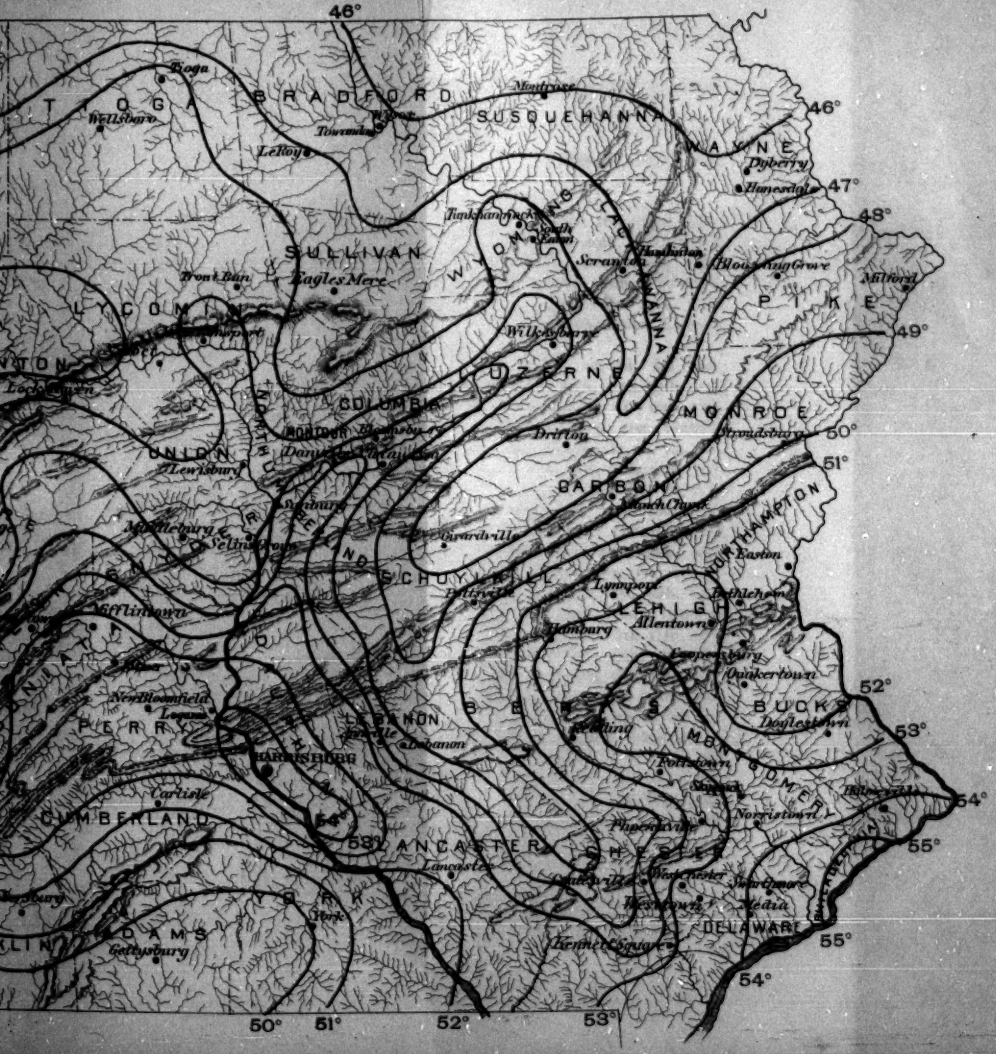
PENNSYLVANIA FOR OCTOBER

State Weather Service.



EXCESSIVE PRECIPITATION.

[One inch in one hour, or two and one-half inches in twenty-four hours.]

Stations.	Amount. (Inches and Hundredths.)	Time		Date.
		h.	m.	
Beaver Dam,	3·44	24	—	13th, 14th.
LeRoy,	2·60	24	—	13th, 14th.
New Castle,	2·63	24	—	13th, 14th.
Swarthmore,	3·00	24	—	22d, 23d.

	Mean Temperature.	*Mean Precipitation. Inches.*
October, 1888,	46°·1	4·03
1889,	47°·3	3·85
1890,	50°·9	5·87
1891,	50°·4	3·06
1892,	50°·5	0·78
1893,	52°·8	3·26

TEMPERATURE.

The mean temperature for October, 1893, was 52°·8, which is 3°·1 above the normal, and 2°·3 above the corresponding month of 1892.

The mean of the daily maximum and minimum temperatures, 63°·9 and 42°·2, gives a monthly mean of 53°·0, with an average daily range of 21°·7.

Highest monthly mean, 58°·0 at Philadelphia. [Weather Bureau.]

Lowest monthly mean, 46°·0 at Wellsboro.

Highest temperature recorded during the month, 91° on the 9th at Coatesville.

Lowest temperature, 17° on the 31st at Hollidaysburg and Smethport.

Greatest local monthly range, 69° at Coatesville and Ligonier.

Least local monthly range, 42° at Altoona.

Greatest daily range, 53° at Ligonier on the 11th.

Least daily range, 2° at Coopersburg, 4th; Chambersburg, 5th; Blue Knob, 15th, and Dyberry, 23d.

BAROMETER.

The mean pressure for the month, 30·10, is about ·03 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·53 at Pittsburgh on the 17th, and the same at Philadelphia on the 19th, and the lowest 29·05 at Erie on the 14th.

PRECIPITATION.

The average rainfall, 3·26 inches for the month, is a deficiency of 0·22 inch.

The largest monthly totals in inches were Blue Knob, 6·58; Beaver Dam, 5·63; Stoyestown, 4·61; New Castle, 4·59; and Kilmer, 4·41 inches.

The least were Bloomsburg, 1·18; Wysox, 1·33; Blooming Grove, 1·51, and Wilkes-Barre, 1·70 inches.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: rainy days, 8; clear days, 14; fair days, 8; cloudy days, 9.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Blue Knob, 14th; Forks of Neshaminy, 27th; Emporium, 24th; Wellsboro, 24th.

Hail.—Blue Knob, 28th.

Snow.—Blue Knob, 15th, 16th, 28th, 29th; Le Roy, 16th, 19th, 30th; Forks of Neshaminy, 30th; Johnstown, 29th; Emporium, 29th, 30th; Mauch Chunk, 30th; Coatesville, 30th; Bloomsburg, 29th; Saegertown, 28th; Coopersburg, 30th; Wilkes-Barre, 30th; Smethport, 28th, 30th; Pottstown, 30th; *Philadelphia* [Centennial Avenue], 30th; Girardville, 29th, 30th; Selins Grove, 29th; Wellsboro, 30th; Dyberry, 29th, 30th; Salem Corners, 16th; Ligonier, 29th; Phœnixville, 29th.

Frost.—Pittsburgh, 18th, 19th, 30th; Blue Knob, 1st, 2d, 8th, 10th, 15th, 16th, 17th, 18th, 19th, 20th, 25th, 26th, 27th, 28th, 29th, 30th, 31st; Hollidaysburg, 1st, 2d, 17th, 18th, 26th, 30th, 31st; Wysox, 1st, 11th, 16th, 17th, 18th, 19th, 26th, 31st; Le Roy, 16th, 17th, 26th, 29th, 30th, 31st; Forks of Neshaminy, 11th, 16th, 17th, 20th, 26th, 30th, 31st; Emporium, 2d, 3d, 10th, 11th, 17th, 18th, 19th, 26th, 31st; Mauch Chunk, 17th, 18th, 26th, 30th, 31st; State College, 1st, 2d, 17th, 18th, 19th. 26th, 31st; Coatesville, 1st, 11th, 17th, 18th, 30th, 31st; Kennett Square, 1st, 11th, 12th, 15th, 18th, 19th, 20th, 23d, 29th, 31st; Westtown, 17th, 18th, 30th, 31st; Grampian, 2d, 17th, 18th, 31st; Lock Haven, 11th, 17th, 18th, 19th, 20th, 26th, 30th, 31st; Bloomsburg, 17th, 18th, 26th, 30th, 31st; Saegertown, 1st, 2d, 3d, 9th, 11th, 12th, 18th, 19th, 27th, 28th, 31st; Carlisle, 1st, 30th, 31st; Harrisburg, 1st, 17th, 18th, 30th, 31st; Edinboro, 29th, 31st; Huntingdon, 2d, 31st; Lancaster, 17th, 26th, 30th, 31st; Lebanon, 1st, 17th, 18th, 26th, 30th, 31st; Coopersburg, 30th, 31st; Drifton, 16th, 17th, 18th, 28th, 30th; Wilkes-Barre, 9th, 17th, 26th, 31st; Easton, 1st, 17th, 18th, 26th, 30th, 31st; *Philadelphia* [Weather Bureau], 17th, 18th, 20th, 26th, 30th, 31st; [Centennial Avenue], 17th, 18th, 20th, 26th, 30th, 31st; Girardville, 8th, 9th, 11th, 12th, 16th, 17th, 18th, 20th, 26th, 28th, 29th, 30th, 31st; Somerset, 1st, 2d, 3d, 8th, 17th, 18th, 19th, 28th; Wellsboro, 1st, 2d, 8th, 11th, 17th, 18th, 19th, 29th, 30th, 31st; Lewisburg, 1st, 2d, 17th, 25th, 26th, 29th, 30th, 31st; Dyberry, 1st, 8th, 11th, 12th, 17th, 18th, 19th, 26th, 30th, 29th, 31st; Honesdale, 1st, 11th, 17th, 18th, 19th, 26th, 29th, 30th, 31st; Salem Corners, 17th, 26th, 30th, 31st; York, 1st, 17th, 18th, 26th, 30th, 31st; Phœnixville, 17th, 18th, 26th, 30th, 31st; Skippack, 1st, 2d, 12th, 16th, 17th, 18th, 20th.

Sleet.—Blue Knob, 21st.

Aurora.—Le Roy, 2d; Selins Grove, 24th; Salem Corners, 1st, 3d, 5th, 8th.

Coronæ.—Emporium, 26th; Lebanon, 25th, 30th.

Solar Halo.—Philadelphia [Centennial Avenue], 12th; Wellsboro, 22d; Dyberry, 26th.

Lunar Halo.—Forks of Neshaminy, 19th; State College, 24th; Lancaster, 20th; Lebanon, 20th; Somerset, 21st; Wellsboro, 26th; Salem Corners, 20th,

Meteors.—State College, 31st; Philadelphia [Centennial Avenue], 17th, 30th.

Parhelias.—Dyberry, 26th.

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189

DECEMBER WEATHER.

From United States Weather Bureau Records.

The following data, compiled from the records of observations taken during the length of time given at each station, show the average and extreme conditions during that time, and also the range within which weather variations may be expected to keep in any future December.

	Philadelphia. (22 years.)	Pittsburgh. (23 years.)	Erie. (20 years.)
Mean or normal,	35°	34°	32°
Warmest December,	1889	1889	1889
Average,	44°	46°	41°
Coldest December,	1876	1876	1876
Average,	25°	23°	22°
Highest temperature recorded,	70°	73°	70°
Date,	4th, 1873	9th, 1885	29th, 1889
Lowest temperature recorded.	Minus 5°	Minus 9°	Minus 11°
Date,	30th, 1880	30th, 1880	30th, 1880
Average date of first "killing" frost,	October 28th	October 21st	October 15th
Average precipitation (inches),	2·71	2·85	3·28
Average number of days with ·01 inch or more,	10	15	20
Greatest monthly precipitation,	5·06	5·64	6·44
Date,	1887	1890	1881
Least monthly precipitation,	0·83	0·83	0·75
Date,	1877	1876	1876
Greatest amount in 24 hours,	2·23	2·35	1·34
Date,	16th and 17th, 1888	16th and 17th, 1890	9th, 1878
Greatest amount snowfall in 24 hours,	6·00	16·50	5·00
Date,	17th, 18th, 1887	16th and 17th, 1890	17th, 1884
Average number clear days,	8	3	2
Partly cloudy,	11	12	7
Cloudy,	12	16	22
Prevailing direction of wind,	NW.	W.	SW.
Highest velocity, miles per hour,	63	40	52
Date,	10th, 1878	16th, 1876	1875, 1876